ARCOM

ASSOCIATION OF RESEARCHERS IN **CONSTRUCTION MANAGEMENT**

THIRTY-FIFTH ANNUAL CONFERENCE 2019

September 2-4

Leeds

PROCEEDINGS

Association of Researchers in Construction Management (ARCOM)

PROCEEDINGS OF THE 35TH ANNUAL CONFERENCE

Edited by Chris Gorse and Christopher J Neilson

First published 2019

978-0-9955463-4-9

Published by

ARCOM, Association of Researchers in Construction Management

Leeds Sustainability Institute, School of the Built Environment and Engineering

Leeds Beckett University

NT107 The Northern Terrace

Leeds

LS2 8AG, UK

Professor Chris Gorse

Leeds Sustainability Institute, School of the Built Environment and Engineering

Leeds Beckett University

NT107 The Northern Terrace

Leeds

LS2 8AG, UK

Email: c.gorse@leedsbeckett.ac.uk

ARCOM Declaration:

The papers in these proceedings were double-blind refereed by members of the scientific committee in a process that involved, detailed reading of the papers, reporting of comments to authors, modifications of papers by authors and re-evaluation of re-submitted papers to ensure quality of content.

Foreword

Welcome from the Chair of ARCOM 2019

Professor Chris Gorse, Leeds Beckett University

Leeds Beckett University extends a warm welcome to the construction management research community and invites all to enjoy the great County of Yorkshire. Yorkshire is the largest and, some would argue, the friendliest County in England. Leeds and the surrounding areas are steeped in history, so during the ARCOM conference, we will be offering a little Northern nostalgia as we spend time at Headingly Campus, holding the social event at Salts Mill World Heritage Site and engage in our local engineering legacy. We will learn from those that shape the world and build knowledge in the 'here and now' as we focus on transformation and a new era of digital innovation.

We have an exceptional conference lined up with leaders and scholars primed to share their experience. Professor Jacqui Glass of the University College London will provide a visionary perspective on a new era for our research as we transform construction. Chair of Operations and Supply Chain Management, Professor Jan Godsell of the University of Warwick, offers insight into the central issue of *integration.* On our second day, we challenge the systems and digital innovation in construction with Professor Jennifer Whyte of Imperial College London, while the Director of Innovation in Construction Dr Wei Pan from the University of Hong Kong, shares his insight of a move from blocks to modules.

We have a distinguished panel helping to push forward the boundaries of the discussion. Joining us will be Professor Charles Egbu President of the CIOB, Dr Chrissi McCarthy Managing Director of Constructing Equality, Joanne Jamieson Managing Director of United Living, Eddie Tuttle CIOB Director of Policy, Research and Public Affairs, Dr Colin Harrop Partner of Sanderson Weatherall, Jonathan Wilson Development Director for CITU and Stuart Norris President of Insulation Manufacturers and Portakabin's Senior Product Development Engineer.

The conference theme this year addresses productivity and performance. The issues of transformation and change are at home in Yorkshire, a County steeped in an ability to harness energy, delivering quality products and services that extend around the globe. Yorkshire's industrial heritage would not have been so influential if it wasn't for the visionary leaders of 'time' that stepped outside of their traditional boundaries with technical and social innovation. Travel and the distribution goods were once extended to the world, by a Yorkshire carpenter, through the invention of John Harrison's timepiece. Without accurately measuring 'time', we would not have been able to safely navigate the seas. Interestingly, time followed a similar path to ARCOM, the concept of the atomic clocks that we use today was first suggested by Lord Kelvin in 1879. Kelvin was born in Belfast with much of his mathematical analysis taking place in Glasgow. As ARCOM moves from Belfast, though Leeds to Glasgow, we are wise to reflect that 'time' is just the interval between events.

Events, such as those of the industrial revolution, shaped the world. Sir Titus Salts of Leeds, still considered a thought leader in modern day manufacture, historically challenged management convention with social and cultural advancement, creating environments to deliver products of exceptional quality form the largest factory in the world at that time. The impact on the local area and community, through the Salt's ethos, was beneficial to the workers' health, education and wellbeing. The Saltaire buildings and artefacts, which were awarded UNESCO World heritage status, show

how important the site is, but the social significance of Salt's vision, possibly has had a much greater influence on working practices today than we are able to truly understand. Social impact, like time, is difficult to measure, but without doubt both are significant in our quest for production and performance. It is a pleasure that the ARCOM community will join us at Leeds Beckett University, to experience Yorkshire, its community and to embrace the experience.

Welcome to ARCOM and Leeds Beckett University.

Chris Gorse

Chris Gorse
Conference Chair, ARCOM 2019

ARCOM Committee for 2018/2019

Professor. Christopher Gorse *(Chair)*	Leeds Beckett University
Professor. Paul W Chan *(Immediate Past Chair)*	Delft University of Technology
Professor. Lloyd Scott (Vice-Chair)	Technological University Dublin
Dr. Apollo Tutesigensi *(Treasurer)*	University of Leeds
Dr. Fred Sherratt *(Secretary)*	Anglia Ruskin University
Dr. Shu-Ling Lu *(Membership Secretary)*	University of Reading
Dr. Robby Soetanto *(Publications Secretary)*	Loughborough University
Dr. Chika Udeaja *(Workshops Convenor)*	University of Salford
Dr. Emmanuel Aboagye-Nimo	Nottingham Trent University
Professor. David Boyd	Birmingham City University
Dr. Vivien Chow	Loughborough University
Dr Alex Copping	University of Bath
Dr Patrick Manu	The University of Manchester
Dr Michael McCarney	Retired Academic/Practitioner
Dr. Alex Opoku	University College London
Dr. Ani Raidén	Nottingham Trent University
Dr. Libby Schweber	University of Reading
Dr. Simon Smith	University of Edinburgh
Dr. John Spillane	University of Limerick
Dr. Craig Thomson	Glasgow Caledonian University
Dr. Niraj Thurairajah	Northumbria University

Scientific Committee 2018/2019

The success of the Annual ARCOM Conference depends on the voluntary efforts of the Scientific Committee. We are indebted to the members of the Scientific Committee who, together with the ARCOM Committee members, provided rigour and constructive feedback in the peer-review process.

Dr Dominic Ahiaga-Dagbui	Deakin University
Dr Saheed Ajayi	Leeds Beckett University
Dr Nii A Ankrah	Aston University
Gihan Badi	Leeds Beckett University
Dr Pablo Ballesteros-Perez	Universidad de Cádiz
Professor David Blackwood	Abertay University
Dr Karen Blay	Loughborough University
Professor Paul Bowen	University of Cape Town
Dr Jim Bradley	University of Limerick
Tara Brooks	Queens University Belfast
Dr Martine Buser	Chalmers University of Technology
Professor Lena Elisabeth Bygballe	Norwegian Business School
Dr Nicola Callaghan	Glasgow Caledonian University
Dr Valerie Caven	Nottingham Trent University
Professor Anita Ceric	University of Zagreb
Dr Chen-Yu Chang	University College London
Associate Professor Nicholas Chileshe	University of South Australia
Daniel M J Clarke-Hagan	Queens University Belfast
Dr William Collinge	The University of Manchester
Professor Martin Crapper	Northumbria University
Dr Qingbin Cui	University of Maryland
Professor Andrew Dainty	Loughborough University
Dr Peter Demian	Loughborough University
James Durrant	Leeds Beckett University
Dr Peter Edwards	RMIT University
Dr Obuks Ejohwomu	The University of Manchester
Dr Fidelis Emuze	Central University of Technology
Associate Professor Jane English	University of Cape Town
Dr Doug Forbes	Whole Life Consultants Limited
Dr Marianne Forman	Aalborg University
Dr Daniel Gilmour	Abertay University
Professor Pernilla Gluch	Chalmers University of Technology
Dr Stefan Christoffer Gottlieb	Aalborg University

Dr Andreas Hartmann	University of Twente
Professor Chris Harty	University of Reading
Dr John Heathcote	Leeds Beckett University
Dr Anthony Higham	University of Salford
Professor Chris Ivory	Anglia Ruskin University
Dr Marcus Jefferies	University of Newcastle
Dr Andrea Jia	National University of Singapore
Dr Sittimont Kanjanabootra	University of Newcastle, Australia
Hadi Kazemi	Leeds Beckett University
Dr Nthatisi Khatleli	University of the Witwatersrand
Professor Dr Christian Koch	Chalmers University of Technology
Dr Martin Löwstedt	Chalmers University of Technology
Professor Henrik Linderoth	Jönköping University
Dr Åse Linné	Uppsala University
Professor Martin Loosemore	University of New South Wales
Dr Emmanuel Manu	Nottingham Trent University
Chrissi McCarthy	Constructing Equality
Dr Grant Mills	University College London
Dr Roisin Murphy	Technological University Dublin
Dr Niamh Murtagh	University College London
Professor Henry Odeyinka	Obafemi Awolowo University
Dr Léon olde Scholtenhuis	University of Twente
Dr Finn Orstavik	University of South-Eastern Norway
Professor David Proverbs	Birmingham City University
Professor Christine Räisänen	Chalmers University of Technology
Dr Mohammad Radfar	Leeds Beckett University
Dr Peter Raisbeck	University of Melbourne
Dr Andrew Ross	Liverpool John Moores University
Professor Paul Stephenson	Sheffield Hallum University
Dr Ian Stewart	The University of Manchester
Dr Subashini Suresh	University of Wolverhampton
Dr Stuart Tennant	University of the West of Scotland
Dr Evelyn Ai Lin Teo	National University of Singapore
Associate Professor David Thorpe	University of Southern Queensland
Professor Leentje Volker	University of Twente
Dr Ruben Vrijhoef	Delft University of Technology
Dr Faye Wade	University of Edinburgh
Dr Vedran Zerjav	University College London
Dr Rita Peihua Zhang	RMIT University
Dr Sam Zulu	Leeds Beckett University

Table of Contents

PROBLEMATISING BUILDING PERFORMANCE

BARRIERS TO EMPLOYMENT FACED BY DISADVANTAGED GROUPS TARGETED BY NEW SOCIAL PROCUREMENT POLICIES

Martin Loosemore[1], Suhair Zaid Alkilani[2] and Robert Mathenge[3]

[1&3] *Faculty of the Built Environment, University of New South Wales, Red Centre Building, University Mall, Kensington, NSW 2033, Australia*

[2] *Australian Pacific International College, Sydney, Australia, NSW 2000, Australia*

Social procurement is an increasingly popular policy mechanism to encourage construction firms to employ people suffering disadvantage in the communities in which they build. However, research into the challenges which policy-makers might face in implementing these new employment requirements. To address this important question, a survey of seventy Australian construction subcontractors shows that the main barriers to the implementation of new social procurement employment requirements are: A lack of government support and incentives; the cost of training, supervision and workplace support for targeted groups; and a perception that these groups are a risk and not able to fit-in and work effectively in the construction industry. These findings provide a more nuanced understanding of the challenges involved in social procurement implementation. This is important in reducing the risk that social procurement policy runs ahead of industry practice and capability to deliver on what are becoming an increasingly complex array of employment requirements.

Keywords: diversity, gender, disability, social procurement, social value

INTRODUCTION

In its simplest terms, social procurement is "the acquisition of a range of assets and services, with the aim of intentionally creating social outcomes (both directly and indirectly)" (Furneaux and Barraket, 2014: 269). As Loosemore (2016) and Raiden et al., (2019) note, this essentially involves requiring a supply chain to create 'social value' either directly (by for example employing disadvantaged people) or indirectly by requiring their supply chain to do the same. While some social procurement policies are agnostic about the disadvantaged groups they seek to help, others are more targeted. For example, in countries like Australia, Canada and South Africa there has been a long-term focus on Indigenous people (see for example the Australian Indigenous Procurement Policy 2015 - Australian Government 2015).

Despite a growing body of research in social procurement outside construction (see for example Barraket et al., 2016), there is a lack of sector-specific research in industries like construction. Nevertheless, while industries like construction offer enormous potential opportunities to help address social challenges through employment for disadvantaged groups, recent research indicates that there are

[1] m.loosemore@unsw.edu.au

Loosemore, M, Alkilani, S Z and Mathenge, R (2019) Barriers to Employment Faced by Disadvantaged Groups Targeted by New Social Procurement Policies *In:* Gorse, C and Neilson, C J (Eds) *Proceedings of the 35th Annual ARCOM Conference,* 2-4 September 2019, Leeds, UK, Association of Researchers in Construction Management, 15-23

numerous challenges to overcome in implementing such policies. For example, Loosemore (2016) and Barraket and Loosemore (2018) found that social procurement is largely driven by commercial imperatives and is constrained by the construction industry's established governance, management, leadership, organisational arrangements, systems, structures and competencies. Petersen's (2018) review of social procurement employment requirements in the Swedish construction industry, shows that the effective implementation of social procurement will require significant institutional change, driven by the need to combine commercial and public interest and new blended forms of institutional logics which see the concept of value more broadly than simply economic.

While the growing body of work on construction social procurement is throwing light on the general institutional changes it may require, less is known about the specific barriers to employment faced by the disadvantaged groups being targeted by social procurement policies. These cohort groups vary from one social procurement policy context to the next in response to community needs and impose a complex and demanding web of new employment requirements on those firms tendering for public and private sector construction contracts that incorporate social procurement requirements. For example, the recently released Victorian Social Procurement Framework in Australia (Victoria State Government 2018) requires all Victorian Government departments and agencies to consider employment targets for Indigenous people, disabled people, women, long-term unemployed, disengaged youth, single parents, migrants and refugees, and workers in transition. For an industry with a strong stereotype image of what the ideal construction worker should look like ("one of a macho, blockey, big muscly able-bodied person, and that this person would probably be a man" Ormerod and Newton 2013: 933) these emerging social procurement requirements present a significant new challenge. It is in within this context that the aim of this paper is to investigate the barriers to social procurement employment requirements in the construction subcontractor supply chain, since this is where the majority will be employed. More specifically, this paper explores the barriers to employment that are likely to be faced by a range of disadvantaged groups commonly targeted by social procurement policies (Indigenous, Disabled, Women, Disengaged Youth, Migrants and Refugees, Ex-Offenders).

Employing the disadvantaged

There has been very little construction management research into the employment of disadvantaged groups typically targeted by social procurement policies. This is somewhat surprising given that some groups (such as Indigenous people, youth and migrants) are heavily represented in the sector. For example, a recent report by Construction Skills Queensland (2018) in Australia found that Indigenous workers are 30% more likely to work in construction than in other industries. The construction industry has therefore become a major focus for Indigenous social procurement policies in countries like Australia, Canada and South Africa (Denny-Smith and Loosemore 2017). However, despite some research into Indigenous construction businesses in countries like Australia, Nigeria and Papua New Guinea (Adams 1997, Dania *et al.,* 2014, Wasi and Skitmore 2001, Denny-Smith and Loosemore 2017) there has been little research into employment of Indigenous people in construction. Disengaged youth (people 15-24 years old who are not engaged in work or study) are another neglected group in construction research, despite the construction industry being a major employer of youth. Indeed, the Australian construction industry is the largest employer of youth of any sector in that country (ABS 2016). Nevertheless, in

many countries, disengaged young people face complex and interrelated barriers to finding and maintaining employment which are often exacerbated in construction due to historical reductions in apprenticeships and training, increasing workplace casualisation, declining working conditions and the lack of capacity to carry unproductive youngsters as they learn their trade due to high time and cost pressures on projects (Chan and McCabe 2010). Although there has been no research into refugees in the construction industry, the employment experiences of immigrants has received some attention with research showing that poor language, discrimination, a lack of locally recognised qualifications and perceived safety and productivity risks are common barriers to employment (Loosemore *et al.,* 2011, Hammond, *et al.,* 2016, Khatleli 2015). Ex-offenders represent another under-researched group in construction, despite the industry offering many opportunities for their reintegration into the workforce and it being a priority industry for government ex-offender rehabilitation in some countries (see for example the UK's National Association for the Care and Resettlement of Offenders 2018).

However, research outside of construction highlights the numerous barriers that they face in gaining employment, which include: lack of education; negative stigmatisation, stereotypes and discrimination; adverse impacts on customers and other employees; safety, security and productivity risks; and the need to manage ongoing interpersonal challenges such as mental health problems, physical, psychological, substance use and a lack of education and skills (Baldry and Russell 2017). Research into disability employment in construction has also been scant but shows that people with disabilities face significant wage differentials, stigmatisation and discrimination by employers (Ormerod and Newton 2013, Quaigrain and Issa 2018). People suffering disability are widely seen as a risk rather than an asset in construction and tend to occupy administrative and office-based roles which preclude them from promotional opportunities given to people in more project-based roles. Of all the disadvantaged groups targeted by new social procurement policies, women represent the most well researched group in construction, revealing a wide range of barriers to employment for women which include the macho culture of the industry; stereotype images of women not being able to work in construction; long work hours and presenteeism; sexism, harassment and discrimination; rigid workplace practices; informal and non-transparent recruitment practices (the old boys network); and subconscious bias - to name just a few (Dainty *et al.,* 2004, Sang and Powell 2012, Lingard and Lin 2012, Galea *et al.,* 2015). However, the vast majority of research has been focussed on women professionals and barriers to employment for women targeted by social procurement policies have received less attention.

METHOD

To investigate the employment barriers that the above groups face in the construction supply chain, an online survey was conducted of subcontractors across the construction supply chain in Australia. The on-line survey comprised two sections. The first section required respondents to provide general demographic information about the nature, employment size, turnover of their company and age of their company. The second part of the survey included questions about: The priorities given to hiring individuals from disadvantaged groups (Indigenous, Disabled, Women, Disengaged Youth, Migrants and Refugees, Ex-Offenders); barriers to employment for these groups; and the past and current representation of disadvantaged groups in the subcontractor supply chain. The questionnaire was pretested with a small sample (10) of subcontractors and respondents were purposefully selected from a sampling frame of individuals who made hiring

decisions in registered sub-contracting organisations across a representative sample frame of trades. A total of 100 sub-contracting businesses in Australia were invited to participate and 70 usable responses were received, a very high response rate as illustrated in Table 1. The responses were analysed by reporting the frequency of responses across all questions and cohort groups.

Table 1 Sample structure

Characteristics	Frequency	Percentage %
Industry experience		
0-5 years	5	7.1
6-10 years	19	27.1
11-15 years	20	28.6
15 and over years	26	37.1
Trade		
Service Trade (ST)	26	37.1
Structural Trade (STT)	27	38.6
Other	17	24.3
Annual turnover		
0 - 1 million dollars	17	24.3
1 - 5 million dollars	29	41.4
5 - 10 million dollars	17	24.3
Over 10 million dollars	7	10.0
Company size		
0 - 10	11	15.7
10 - 50	43	61.4
50 - 100	14	20.0
over 100	2	2.9

RESULTS AND DISCUSSION

Table 2 shows the perceived barriers to employment for each group and Table 3 shows the relative barriers to employment in rank order for each cohort group. It is notable how varied the barriers to employment are across the different disadvantaged cohort groups. This indicates the complex challenges which policy-makers may have in providing support for the implementation of their social procurement policies.

In Table 2, lack of government support ranks as the highest 'overall' barrier to the employment of these groups which suggests that social procurement legislation is not being accompanied by the necessary support structures to enable it to be implemented effectively. Reading horizontally across each row, this is the biggest barrier for disengaged youth and ex-offenders with women coming a close second. Not surprisingly, this is the least problem for indigenous and disabled people since the Australian government has put significant resources into these areas. Nevertheless, the inclusion of women is a surprise given the enormous focus on gender diversity in construction and in Australian business more widely (Galea *et al.,* 2015). Our results suggest that this may not be filtering down to subcontractor level.

Since lack of government support ranked as the highest barrier across all cohort groups our results suggest that governments may need to rethink the support, they offer to help industry implement these policies. This is especially important given Loosemore and Reid's (2018) recommendation that building supply chain capacity in

existing subcontracting companies should be a priority for governments in supporting the implementation of their new social procurement policies (rather than relying on social enterprise development as much policy and research does). Given Loosemore and Lim's (2018) recent research which showed that subcontractor corporate social responsibility (CSR) practices in the construction sector are largely compliance-based, our findings suggest that policy-makers may be under-estimating the support that is needed in an industry that cannot be counted-on to respond in a values-driven context. In terms of the type of support needed, there is little existing research. However, our results indicate that policies that provide monetary support to employers and which

Table 2: Perceived barriers to the employment compared across disadvantage groups

Barriers	Overall			Indigenous			Disabled			Women			Disengaged Youth			Migrants & Refugees			Ex-Offenders		
	∑	%	Rank	F	%	Rank	F	%	Rank	F	%	Rank	F	%	Rank	F	%	Rank	F	%	Rank
Lack of support	360	85.7	1	48	68.5	5	49	70	4	68	97.14	2	69	98.57	1	57	81.43	3	69	98.57	1
Cost of training	319	75.9	2	33	47.1	6	7	100	1	43	61.4	4	68	97.1	2	65	92.8	3	40	57.1	5
Inability to fit in	226	53.8	3	3	4.29	6	50	71.4	3	59	84.2	1	19	27.1	5	57	81.4	2	38	54.2	4
Low technical skills	207	49.2	4	3	4.29	6	51	72.8	3	34	48.5	4	55	78.5	1	52	74.2	2	12	17.1	5
Cannot work long hours	207	49.2	4	0	0	6	69	98.5	1	68	97.1	2	67	95.7	3	1	1.43	5	2	2.86	4
Cost of supervision	205	48.8	5	8	11.4	6	69	98.5	1	12	17.1	5	67	95.7	2	30	42.8	3	19	27.1	4
Poor productivity	200	47.6	6	2	2.86	5	5	7.14	4	8	11.4	3	47	67.1	2	69	98.5	1	69	98.5	1
Untrustworthy	185	44.0	7	38	54.2	3	0	0.00	5	0	0.00	5	64	91.4	1	26	37.1	4	57	81.4	2
Work commitment	182	43.3	8	0	0	5	57	81.4	2	40	57.1	3	70	100	1	0	0	5	15	21.4	4
Cause of conflict	179	42.6	9	39	55.7	3	0	0	5	0	0	5	65	92.8	1	11	15.7	4	64	91.4	2
Lack qualifications	170	40.4	10	39	55.7	3	3	4.29	5	0	0	6	50	71.4	2	70	100	1	8	11.4	4
Risk to reputation	168	40.0	11	24	34.2	3	0	0	5	0	0	5	66	94.2	2	8	11.4	4	70	100	1
Literacy/numeracy	166	39.5	12	29	41.4	3	5	7.14	4	0	0	6	63	90	2	67	95.71	1	2	2.86	5
Poor education	164	39.0	13	30	42.8	3	3	4.29	4	0	0	6	60	85.7	2	70	100	1	1	1.43	5
Cultural differences	138	32.8	14	62	88.5	2	0	0.00	5	6	8.57	3	1	1.43	4	69	98.5	1	0	0.00	5
Unreliability	131	31.1	15	0	0	5	49	70	2	6	8.57	3	69	98.5	1	1	1.43	4	6	8.57	3
Poor communication	118	28.1	16	8	11.4	3	0	0.00	4	0	0.00	4	39	55.7	2	70	100	1	1	1.43	3
Modifying workplace	115	27.3	17	0	0	3	70	100	1	45	64.2	2	0	0	3	0	0	3	0	0	3
Health needs	113	26.9	18	1	1.43	3	70	100	1	42	60	2	0	0	4	0	0	4	0	0	4
Poor work quality	108	25.7	19	0	0	5	37	52.8	2	2	2.86	3	68	97.1	1	0	0	5	1	1.43	4

*Note: Sum= the frequency of all "Yes" answer by all participants for all disadvantage groups per barrier; F= frequency of "Yes" answer for the barrier by all participants for each disadvantage group; % for overall is the sum divided by (70*6) *100; % for each disadvantage group is the frequency divided by 70*

provide training to employees to make them productive and safe would be most effective since our respondents perceived the disadvantaged groups we explored to require more training and supervision and to work at lower productivity rates than other employees. For example, in Australia, there are a number of financial incentives and wage subsidies to help companies employ eligible job seekers including disabled, young people, mature age, long-term unemployed, Indigenous, or principal carer parents (Jobactive 2019). A lack of technical skills is also something that government can address through the provision of targeted training subsidies to address historical educational disadvantage in many groups. For example, in the context of Indigenous people, Perry (2017) shows that educational disadvantage is a major problem - especially for those who live in regional areas. According to Legrain (2017), other useful educational initiatives, for groups such as refugees and migrants include those to enable the upgrading of qualifications to local standards or to have existing qualifications better recognised in a local context.

In addition to a lack of support, Table 2 also shows that subcontractors are concerned about the costs of complying with these new social procurement requirements which is not surprising given the highly competitive nature of the construction supply chain and market. Since most jobs are won on small differences between subcontractor price, the employment of these disadvantaged groups could make the difference between winning a job or not. However, we note that there is currently no reliable data on the extra costs (if any) of employing these cohort groups, and more research is needed in this area. Looking across the various groups in Table 2, perceived extra costs is the largest issue for disabled people (100% of the sample ticked this box), followed by disengaged youth and migrants and refugees. The third greatest barrier in Table 2 is the inability of these cohorts to fit in to the traditional construction workforce with women, migrant refugees and then disabled people suffering the most. There is a significant body of work reviewed earlier which shows that construction has traditionally excluded these groups from the workforce, and it would seem that these people are still seen as outsiders.

Other prominent barriers include: lack of technical skills (disengaged youth, migrants and refugees, disabled); inability to work long hours (disabled, women and disengaged youth); cost of supervision (disabled and disengaged youth); low work productivity (ex-offenders and refugees and migrants); untrustworthiness, (disengaged youth and ex-offenders); lack of commitment (disengaged youth, disabled); and cause of workplace conflict (disengaged youth, ex-offenders). In Table 2, the average 'overall ranking' across all barriers for each cohort group is as follows: disengaged youth (2.1); migrants and refugees (2.85); Disabled (3.1); and ex-offenders (3.45); women (3.7); and Indigenous (4.2). In other words, across the range of barriers we identified in our survey, disengaged youth face the highest perceived barriers to employment in the construction supply chain, followed by migrants and refugees, disabled etc. This indicates where policy-makers should focus their attention in providing support to implement their policies.

The prominence of disengaged youth as the most disadvantaged group is somewhat surprising given the industry is the largest employer of youth in Australia. There is clearly a need for much more research into this group since very little currently exists in construction apart from notable exceptions such as Chan and McCabe (2010).

Table 3: Perceived barriers to the employment for each disadvantage group

Barriers	Rank of Barriers for each Individual Disadvantage Group					
	Indigenous	Disabled	Women	Disengaged Youth	Migrants & Refugees	Ex-Offenders
Lack of support	2	6	1	2	5	2
Cost of training	5	1	5	3	4	5
Inability to fit in	10	5	2	12	5	6
Low technical skills	10	4	8	9	6	12
Can't work long hours	14	2	1	4	12	9
Cost of supervision	9	2	9	4	7	7
Poor productivity	11	2	3	2	11	10
Untrustworthy	4	10	12	6	8	4
Work commitment	14	3	7	1	13	8
Cause of conflict	3	10	12	5	9	3
Lack qualifications	3	9	12	10	1	10
Risk to reputation	8	10	12	5	10	1
Literacy/numeracy	7	8	12	7	3	12
Poor education	6	9	12	8	1	13
Cultural differences	1	10	10	13	2	14
Unreliability	14	6	10	2	12	11
Poor communication	9	10	12	11	1	13
Modifying workplace	14	1	4	14	13	14
Health needs	13	1	6	14	13	14
Poor work quality	14	7	11	3	13	13

CONCLUSIONS

This paper aimed to investigate the barriers to employment that are likely to be faced by a range of disadvantaged groups commonly targeted by social procurement policies. It is clear from our research that emerging social procurement policies are imposing an onerous, complex and overlapping set of employment requirements on a construction supply chain which is neither experienced nor equipped to meet them. If the barriers we have exposed are not addressed, then there is a real danger that policy will run ahead of practice and that the ambitious targets being set will not be met. Our results indicate that policies which not only set targets, but which also provide support and removes barriers to employment could be a powerful way for social procurement policy-makers to encourage the employment of disadvantaged groups in the construction supply chain. Setting targets without an understanding of supply chain capacity to deliver on those targets is likely to be counter-productive and undermine the intend of these policies.

REFERENCES

ABS (2016) *Labour Force, Australia, Detailed, Quarterly, May 2016 - 6291.0.55.003*. Canberra: Australian Bureau of Statistics.

Adams, O (1997) Contractor development in Nigeria: Perceptions of contractors and professionals, *Construction Management and Economics*, 15(**1**), 95-108.

Australian Government (2015) *Commonwealth Indigenous Procurement Policy: 1 July 2015*. Canberra, Australian Government.

Baldry, E and Russell, S (2017) *The Booming Industry Continued: Australian Prisons: A 2017 Update*. Sydney: UNSW, 3-15.

Barraket, J, Keast, R and Furneaux, C (2016) *Social Procurement and New Public Governance*. New York: Routledge.

Barraket, J and Loosemore, M (2018) Co-creating social value through cross-sector collaboration between social enterprises and the construction industry, *Construction Management and Economics*, 36(**07**), 394-408.

Brewer K (2017) *After the Crime: Why Employees Should Give Ex-Offenders a Working Chance*. The Guardian. Available from https://www.theguardian.com/careers/2017/jun/28/after-the-why-employers-should-give-ex-offenders-a-working-chance [Accessed 2/11/2018].

Chan, P W and McCabe, S (2010) Emerging disparities: Exploring the impacts of the financial crisis on the UK construction labour market. *In:* Egbu, C (Ed.) *Proceedings of the 26th Annual ARCOM Conference*, 6-8 September 2010, Leeds, UK Association of Researchers in Construction Management, Vol 1, 523-32.

Construction skills Queensland (2018) *Aboriginal and Torres Strait Islander People in Queensland's Construction Industry*. Construction Skills Queensland, Brisbane, Queensland, Australia.

Dania, A A, Larsen, G D and Ewart, I J (2014) Sustainable construction: Exploring the capabilities of Nigerian construction firms *In:* Raiden, A and Aboagye-Nimo, E (Eds.) *Proceedings of the 30th Annual ARCOM Conference*, 1-3 September 2014, Portsmouth, UK, Association of Researchers in Construction Management, 3-12.

Dainty, A R, Bagilhole, B M, Ansari, K H and Jackson, J (2004) Creating equality in the construction industry: An agenda for change for women and ethnic minorities. *Journal of Construction Research*, 5(**1**), 75-86.

Denny-Smith, G and Loosemore, M (2017) Integrating Indigenous enterprises into the Australian construction industry. *Engineering, Construction and Architectural Management*, 24(**5**), 788-808.

Furneaux, C and Barraket, J (2014) Purchasing social good(s) a definition and typology of social procurement, *Public Money and Management*, 34(**4**), 265-272.

Galea, N, Powell, A, Loosemore M and Chappell, L (2015) Designing robust and revisable policies for gender equality: Lessons from the Australian Construction industry, *Construction Management and Economics*, 33(**5-6**), 375-389.

Jobactive (2019) *Wages Subsidies*. Available from https://jobsearch.gov.au/employer-info/wage-subsidies [Accessed 14/3/2019].

Khatleli, N (2015) The impact of nativist exclusion on the migrant labourers in the South African construction industry. *In:* Raiden, A and Aboagye-Nimo, E (Eds.) *Proceedings of the 31st Annual ARCOM Conference*, 7-9 September 2015, Lincoln, UK Association of Researchers in Construction Management, 217-226.

Legrain, P (2017) *How To Get Refugees Into Work Quickly*. Opennetwork, Copenhagen, Denmark

Lingard, H and Lin, J (2004) Career, family and work environment determinants of organizational commitment among women in the Australian construction industry, *Construction Management and Economics*, 22(**4**), 409-420.

Loosemore M, Florence T, Phua, T, Dunn, K and Ozguc, U (2011) The politics of sameness in the Australian construction industry: Comparing operative and manager attitudes towards cultural diversity, *Engineering, Construction and Architectural Management*, 18(4), 363- 380.

Loosemore M and Reid S (2018) The social procurement practices of tier-one construction contractors in Australia, *Construction Management and Economics*, 37(**10**), 1-18.

Loosemore M and Lim B (2018) Mapping corporate social responsibility strategies in the construction and engineering industry, *Construction Management and Economics*, 36(2), 67-82.

National Association for the Care and Resettlement of Offenders (2018) *Mind the Gap, A Practical Guide to Employing Ex-Offenders in the Construction Industry*. London, UK: National Association for the care and resettlement of offenders.

Ormerod, M and Newton, R (2013) Construction as a career choice for young disabled people: Dispelling the myths, *Construction Management and Economics*, 31(**8**), 928-38.

Petersen, D (2018) *Let the Right Ones In? Employment Requirements in Swedish Construction Procurement*. Chalmers University of technology, Gothenburg, Sweden.

Quaigrain, R A and Issa, M H (2018) Development and validation of disability management indicators for the construction industry, *Journal of Engineering, Design and Technology,* 16(**1**), 81-100.

Raiden A, Loosemore M, King A and Gorse C (2019) *Social Value in Construction.* Abingdon, UK: Routledge.

Sang, K and Powell, A, (2012) Gender inequality in the construction industry: Lessons from Pierre Bourdieu. *In*: *Proceedings of the 28th Annual ARCOM Conference*, Edinburgh, UK: Association of Researchers in Construction Management, 237-247.

Victoria State Government (2018) *Victoria's Social Procurement Framework*. Melbourne, Victoria State Government, 1-46.

Wasi, D and Skitmore, M (2001) Factors affecting the performance of small indigenous contractors in Papua New Guinea, *Australian Journal of Construction Economics and Building*, 1(**1**), 80-90.

SOCIAL PROCUREMENT IN THE REAL WORLD: HOW EMPLOYMENT REQUIREMENTS UNFOLD IN CONSTRUCTION PROJECTS

Daniella Troje[1] and Pernilla Gluch

Department of Technology Management and Economics, Chalmers University of Technology, Vera Sandbergs Allé 8, SE-412 96, Göteborg, Sweden

In hopes of mitigating issues with segregation, unemployment and a lack of workers in the construction sector, social procurement and employment requirements are becoming increasingly popular. Albeit high on the policy and industry agenda, little is known of its effects for practitioners and the newly employed themselves, when they face these in practice. With an aim to understand how social procurement and employment requirements unfold in practice, what effects this has for construction practitioners, for the interns themselves, and for individual projects and organizations, 23 semi-structured interviews were conducted with practitioners and interns in three cases where employment requirements have been applied. The findings show that for practitioners, employment requirements place new demands on themselves as "receivers" of interns, which require personal engagement. For the interns, demands are set on how they should engage in their internship and to seize the opportunity, while same-time facing a risk to become overexposed for advertisement purposes if they perform well. For the construction projects a concern is raised regarding safety, due to the interns' poor language proficiency. However, also positive effects are seen, such as improved team spirit among the project members and added value to the working life of the intern supervisors.

Keywords: employment requirements, social procurement, interns, Sweden

INTRODUCTION

Social criteria are increasingly used in construction procurement, where social criteria relating to employment of vulnerable groups are one of the more widely used types (Montalban-Domingo *et al.,* 2019). With the objective to mitigate issues with social exclusion and unemployment among certain demographic groups, like immigrants, youths, or disabled people (Enochsson and Andersson 2016) employment requirements (ER) is becoming more frequently used in Swedish procurement practice (Upphandlingsmyndigheten 2019). Several Swedish construction and real estate organizations also see employment requirements as a tool for recruitment, where the beforementioned demographics are an untapped source of possible employees, which is needed to meet the high demand for construction in Sweden (ibid).

Although social procurement has been used throughout the 1900's to enact social policies (McCrudden 2004), the recent wave of social procurement initiatives is just now taking form, with some countries being ahead of others. In Scotland,

[1] daniella.troje@chalmers.se

Troje, D and Gluch, P (2019) Social Procurement in the Real World: How Employment Requirements Unfold in Construction Projects *In:* Gorse, C and Neilson, C J (Eds) *Proceedings of the 35th Annual ARCOM Conference,* 2-4 September 2019, Leeds, UK, Association of Researchers in Construction Management, 24-33.

employment requirements (there called community benefit clauses) have become business as usual, and in both Scotland and North Ireland specific work roles, aimed exclusively at working with social procurement, are becoming increasingly common (Sutherland *et al.,* 2015; Murphy and Eadie 2019). This development is also seen in Sweden (Troje and Gluch 2019).

Many actors within the sector are positive towards social procurement, and believe it is a good tool for enabling knowledge sharing, building competences, deeper collaboration throughout the supply chain, meeting client demands, and employment creation (Erridge 2007; Sutherland *et al.,* 2015; Barraket *et al.,* 2016, Murphy and Eadie 2019). At the same time, some scepticism persists in how social procurement may cost more than traditional procurement, that it may displace "ordinary" workers, and that employment requirements are difficult to evaluate (Erridge 2007; Walker and Brammer, 2009; Zuo *et al.,* 2012; Eadie and Rafferty 2014; Barraket *et al.,* 2016; Loosemore 2016). To address some of these issues and to ensure that the "right" social value is created, Murphy and Eadie (2019) suggest that social procurement should adopt a more person-centric approach, where bespoke practices for each newly employed is established according to their needs and skills.

In Sweden, social procurement is rather novel, and as of today no industry-wide best practice exist (Sävfenberg 2017; Troje and Kadefors 2018). Nevertheless, interviewed pioneers state that when it comes to implementing employment requirements in Sweden, there are high prospects that employment requirements will mitigate problems such as unemployment, segregation and also provide the sector with new labour (Troje and Gluch 2019). The issue of social procurement is thus high on the policy and industry agenda, but less is done in regard to an empirical examination of its effects and how employment requirements actually work in practice (Troje and Gluch 2019). To fill this gap this paper investigates the practical effects of employment requirements for practitioners, as well as for the newly employed themselves when they face employment requirements in their every-day work life.

Perspectives on Social Procurement

Employment issues in social procurement have covered everything from fair working hours and wages, employment of disabled veterans in the UK, affirmative action for African Americans in the US, and the treatment of aboriginal populations in Canada (McCrudden 2004). Studies have focused on measures to benefit local, small, or minority-owned businesses (Walker and Preuss 2008, Loader 2012, Loosemore and Denny-Smith 2016) as well as on social enterprises (Loosemore 2016). Although there is a general lack of knowledge about social procurement in the construction sector (Walker and Brammer 2009; Zuo *et al.,* 2012), some studies discuss benefits of and barriers to social procurement (for examples see Erridge 2007; Eadie and Rafferty 2014; Barraket *et al.,* 2016). However, there is scant research of what employment requirement means for the workers closest to the newly employed, what this means for how they organize their work, and how they cope with incorporating a social value initiative in their daily work. Erridge's (2007) mixed-methods study of a pilot project consisting of several contracts using employment requirements in Northern Ireland is an exception. He found that few respondents perceived that employment requirements increased the administrative work load. However, training was lacking for the newly employed who had no construction background. Despite of this, the jobs were sustainable over time, where 46 out of 51 people employed through the employment requirements maintained their employment after the project ended. However, he also

states that there is a need to ensure to not over-emphasize commercial goals, as these may undermine the achievement of socio-economic goals (ibid.).

Social procurement can thus bring successful outcomes both for construction practitioners and the newly employed, but it may also be difficult as social procurement comes with a different set of logics than traditional construction procurement (Petersen 2018). Firstly, social procurement does not focus on easy-to-measure tangible criteria such as price or quality; and discards a market logic for a social value logic (ibid.). Social procurement thus entails a deviation from traditional work practices and instead aims to deliver social value, which lies outside of the contractor's area of expertise (Murphy and Eadie 2019). Secondly, social criteria do not pertain directly to the object of procurement. Third, the construction sector is characterized by loosely coupled actors who collaborate while maintaining some level of independence and agency (Dubois and Gadde 2002). In social procurement, clients are suddenly dictating what type of workers contractors should hired, e.g. unemployed immigrants (Petersen 2018). Social procurement thus majorly differs from traditional construction procurement, potentially leading to conflicts between institutional logics.

One way of looking at social criteria is in the form of an innovation. Kurdve and de Goey (2017) studied a project where unemployed people were given employment to build standardized modular houses. This created simple jobs in the construction sector for immigrants lacking construction experience, as well as created more temporary housing. Here employment of marginalised groups is a kind of service for the municipality, who often also is the customer of the temporary modular housing (Kurdve and de Goey 2017). In contrast, in North Ireland Murphy and Eadie (2019) found that social procurement is largely being driven by social legislation and is by contractors seen as a contractual obligation rather than a tool for social innovation.

METHOD

To study practical effects of employment requirements, a qualitative research approach was employed, which capture actions, thoughts and beliefs of the ones studied (Silverman 2013). This study includes three different cases where interns were employed due to employment requirements (ER) posed by the construction client. Thus, we refer to these interns as ER interns since they differ from regular interns in the sense that they come from disadvantaged backgrounds and are stigmatized in the labour market. For immigrants, they may have poor Swedish skills, may come from traumas, or have undocumented and inconsistent schooling. For people with disabilities they may have physical or mental barriers to overcome in the work place. ER interns thus have backgrounds and special needs regular interns do not. The first case is a construction project of apartment housing (AH) for a private housing company. The second case is a construction project of a public pre-school (PS). Both construction projects are built by the same large Swedish construction company where the two different clients had posed employment requirements to employ ER interns. The third case is a specific model used by a group of public housing companies (PHG) to create employment opportunities in form of internships for unemployed immigrants in their subsidiary companies.

By the help of managers at both the large Swedish contractor in case 1 and 2 and in the public housing group, interviewees for the study were identified, which led to 23 semi-structured interviews (Kvale 2007). The interviewees are henceforth referred to by an anonymous code (see table 1). The interviewees from the AH and PS cases work with production, mostly on site, or closely with implementing the employment

requirements from the client organization side. Interviewees from the case PHG work with building maintenance in the different subsidiary housing companies. Thus, the interviewees from all cases have experienced practical effects from the employment requirements, and also work on a daily basis with the ER interns.

Table 1: List of interviewees

Project	Client relationship	Example of roles	Individual interviewee codes
Apartment housing (AH)	Private for private	District manager, project manager, site manager, ER intern	AH 1–7
Pre-school (PS)	Private for public	District manager, project manager, site manager, work leader, ER intern, public procurement officer	PS 1–6
Public housing group (PHG)	Public for public (internal client)	Facilities maintainers of buildings and green areas, ER intern	PHG 1–10

Data was collected during autumn 2018-spring 2019. The interviews, which lasted for about one hour, focused on the interviewees' perceptions and experiences, positive and negative, from employment requirements, how it affects their daily work, and what changes in their practices they had to make to accommodate the ER interns. The interviews were transcribed verbatim, and to enable a systematic review data was coded in a software program (NVivo). To identify common themes all the material was first inductively coded according to topics discussed in the interviews. This inductive coding allowed for unexpected patterns to emerge, which was important considering that social procurement is rather unexamined both academically and empirically (Edmondson and McManus 2007). Then, to ensure that the codes reflected the material as accurately as possible all codes were re-coded in order to refine the coding structure. After these two coding rounds 11 categories of codes emerged: (1) work tasks, processes and experiences with ER, (2) resources to work with ER, (3) choice of ER interns, (4) employment terms and contact with government bodies, (5) future for ER interns, (6) working tasks of ER interns, (7) ER interns' perceptions of their working life, (8) what worked well, (9) what worked poorly, (10) relationships between project participants, and (11) current form and future development of employment requirement practice. From these 11 categories of codes, three main themes were identified, concerning effects for (1) the construction practitioners, (2) the ER interns, and for (3) the project and organization. These three themes were analysed using the theoretical framework of previous research on social procurement.

FINDINGS

Practical effects for the construction practitioners

Many of the interviewees explained how they as "receiver" of the ER interns felt pressured by a personal expectation to provide the ER interns with meaningful work. They stressed the importance of having the right prerequisites to achieve this: "Having targets [with employment requirements] are important, but other things are also important […] You have to be able to create the right conditions for things to work. It comes down to the people, the intern and the supervisor, but also the employer […] It's about creating opportunities for relationships and situations where people can grow" (PHG1).

Further, the interviewees expressed how they wanted to ensure that they as a supervisor can support the ER interns so they could provide a 'high quality internship' with fair working conditions. They felt, for example, uncertainties regarding if the ER interns got a fair compensation for their work, which put unnecessary stress on them.

In the pre-school project the team have been struggling with such issues several times. One interviewee described a situation where one ER intern was without pay for a several weeks, but how they have now learnt from those experiences: "Something that we've learnt, is that when somebody new comes here, we ask them on their first day what their compensation is. And if we don't think it's okay, then we have the option of having them on a paid internship for three months instead. So, they get fair compensation. It needs to feel fair for all of us" (PS2). Nevertheless, many of the interviewees realized some uncertainties regarding compensation might be acceptable in the short-term, since main focus is on creating job opportunities. One interviewee (PHG2) explained his view: "I think that for those who come here, they should be able to count on us and feel that when they've gone through with this [internship] they have a chance to get a job. That has to be the most important thing".

This pressure to be a "good" supervisor led to a high degree of personal engagement in the ER interns as persons, and not only in their work. Even though many interviewees who work as supervisors had been advised to uphold a strictly professional relationship with the ER interns, many found this difficult since there were so many private things that the interns also need help with, for example reading Swedish emails, paying bills, writing CVs, and even helping them find new housing for them and their families: "They come with their bills, and ask for help how to pay them. We were told [at the supervisor course] not to do that, but it's difficult when they don't understand how to do it. To help write CVs and fill in applications, …. You're not supposed to do that, but it depends on the person, how you engage. It becomes emotional, …" (PHG5). For the interviewees, supervising the ER interns opened a possibility to meet the people "behind the news reports", e.g. relating to the 2015 refugee crisis. Here employment requirements provided a space to meet people they would not normally meet, and many stories of different situations where this became particularly clear was told during the interview. Sweden being a cold country provided one such story: "He [an intern originally from Africa] had so much clothes on but was still cold. ... And it's not like he was saying that 'I won't go out', because he does what he's supposed to do. The other day it was really cold, and we were down by the harbour, I needed to change a bulb in a light post. It's kind of tricky, and it takes some time with the light fixtures, so I let him stay in the car. I put the heat on and let him stay in the car" (PHG3).

Getting personally engaged with the ER interns provided a feeling that the interviewees were contributing to them personally, as well as to wider society, one interviewee (PHG2) said: "[The intern] told me that after he had gotten employment, he got his life back. I think that's big, it's very cool.". Another interviewee (PHG1) said "I think it is kind of dope, to work for a company that has ambitions that go beyond the quarterly reports". Although the interviewees tend to become personally involved with the ER interns and their lives, they also struggle with an uncertainty that their work might not actually have any long-term positive effects for the ER interns. There is scant follow-up regarding how many of the interns receives permanent employment, and there is no formal feedback of what happens with specific ER interns. In the case where the interviewees know what happened to their interns after the internship ended, it is often because they have stayed in personal contact with the intern, or that they found out by chance, e.g. by running in to them outside of work: "With some interns I don't know what happened. I think that is a shame, that we don't get information on what happened with those that we've worked with for 6 months. But one lives here in the area, so I see him sometimes. It's great when he

tells me how things are going. When you work with someone three days a week, you talk about life, problems, you get engaged in their lives, perhaps more than you should" (PHG5).

Practical effects for the ER interns

The interviewees also felt that in order to offer high quality internships, demands also need to be set also on the ER interns: "We make our working place and resources available in order to help people. And if they don't want help, then I don't think it's our role to try and coax and nag them to come here. In those cases, we have simply ended [the internship]" (AH1). The ER interns themselves are expected to be equally engaged in their work: "As a supervisor, I have some level of responsibility, but that is of course shared with the intern. You have a shared responsibility that the [internship] is a meaningful time, because you don't get rich coming here. Instead you hopefully gain experience and know more things when you leave. So that is a responsibility. […] I offer many opportunities for those that are ready to take them, to practice their abilities to hold a conversation in Swedish" (PHG1). An example of creating meaningful work even when the ER intern cannot contribute much, or is out of their element, e.g. due to meetings held in Swedish, is: "It's about finding a meaningful perspective in different contexts, it can be a meeting of some sort, with a contractor, or an internal meeting [in Swedish]. So, the intern shouldn't just zone out [because of language], to think that this goes above one's head. Instead, don't mind the language, grab some words from the PowerPoint!" (PHG1). On the flipside, when internships have been going well this can lead to an overexposure of the ER interns, who can be used for advertisements: "When we take someone in, I think they are just like anybody else. I can notice a tendency that some wants to raise this all the time, and I don't like that. It bothers me because they are people and I have taken them in because of who they are, but there are many who wants to sell [employment requirements], and that doesn't feel right to me" (PS4).

Practical effects for the project and organization

A major difficulty and barrier for ER to be fully implemented is said to be language issues, but also a lack of understanding of the Swedish work culture: "It's been more demanding than what I thought. The most difficult thing with the interns [refugees] is the language, to make yourself understood. Because they need to understand me and I need to understand them. That's the difficult part" (PHG5). Also, some of the day-to-day tasks of the supervisors, and thereby the accompanying ER interns, includes much communication with residents and tenants: "It's a lot of language in the role of a building maintainer, it's about communication, both with tenants and contractors" (PHG1). Not only does this hinder the socialization of the ER intern into the work group, but it also makes supervision difficult, and increases safety issues, in relation to the heavy machinery operated in both construction and in building maintenance. One interviewee (PHG3) explained: "Safety is very, very important. And that includes everything from how you lift tings to how you handle machinery. For example, a handheld grass mower with a motor: To try and explain to someone who doesn't know that many Swedish words, that you can absolutely never ever put your fingers under the machine. Things like that are very important".

In addition, there are other difficulties in relation to the projects themselves, which may hinder employment requirements. An interviewee (PS2) summarized the issue, relating to the size of the project, the nature of the work, and lack of suitable candidates: "In a big project, they have much more diverse tasks, so there I can

imagine that you can employ people without a background in construction", and "We explained to the municipality, we cannot take anyone. If they are supposed to be a carpenter apprentice, they must know some basics, to use the tools. So we can't just take in a layman carpenter", and "We formulated this contract that we would take in ten interns. But after a while we realized that we will never reach ten interns, so the original idea wasn't well-thought out".

At the same time as there are many practical barriers connected to employment requirements and the ER interns, the interviewees emphasize how they are ordinary employees, and are doing a job like anybody else: "I have chosen all of them because I think they add value to our group, not because of where they come from" (AH1). In addition, they are expected to perform real tasks on real terms: "There are no simple jobs. Some think [the interns] should only pick up trash. But they come along and do the same job we do […] They shouldn't only do the boring tasks […] They must feel like they're here on the same terms as we are, because I wouldn't want to go to Iraq and only pick up trash. They need to be involved and be able to see that you can advance [in your career]. The more you learn the more you can climb the ladder […] They should have all the possibilities" (PHG2). Although their status is emphasized as "just like anybody else", there are instances where the interns' status is very different from the rest of the staff, particularly in relation to their compensation, which we gave examples on earlier.

Besides (the ambition to) perform work like everybody else, the ER interns and employment requirements create perceived added value for a larger system outside of the individual project and organization. When a work group jointly engages in an intern it ties the team closer together. Because taking on ER interns does require some adjustments, it is seen as a receipt that the team is well functioning overall if the team can also successfully take on an intern: "Everybody got very engaged, and of course that creates team spirit. And everybody was very concerned that [the intern] would do well. So, in such a situation, it brings the team closer together" (PS2).

For the interviewees added value was found also on a more personal level: "I think [working with the interns] gives me some sort of added value in my employment" (PHG1). Another interviewee (PHG3) said: "I feel all the time that I am happy to be able to help, to help a person who hopefully shall live and feel good here, to have a good life, that work, and everybody benefits from. If people around us are feeling good, then we all feel good […] To get to know the person and have fun together". At the same time, many of the interviewees stress that even though they are generally positive towards employment requirements and the effects it might bring, it is not a "be all end all" solution: "I think it's great that we're doing this, we give these people a chance. But we have to ensure that we get results in the end. We can't succeed with everybody, but we should have the goal that everybody gets employment" (PHG2), and "As a society, we must understand that [employment requirements] are not what will fix the segregation. It's a small complement where a few can succeed" (AH1).

DISCUSSION

As shown from the findings, many things happen when employment requirements are used and ER interns are taken in, for construction practitioners, for the ER interns themselves, and for the projects and organizations. Something interesting is how the projects and organizations must make accommodations as the ER interns have language barriers and often no background within construction or building maintenance, resulting in some tasks being difficult (e.g. communicating with

tenants), and some task being dangerous (e.g. operating heavy machinery). This mirrors much of Erridge's (2007) findings regarding a lack of training for interns. At the same time, the ER interns are to be treated like any other employee, performing the same tasks as their colleagues and supervisors as "there are no simple jobs". In this sense, there is a contradiction in the way the ER interns are viewed. On the one hand adjustment in daily practices must be made, but on the other the ER interns and their work should not be acknowledged as any different. The question then becomes if this contradiction hinders or helps the ER interns in their journey of finding permanent employment and learning Swedish. If ER interns are not given proper support, they may miss out on learning opportunities because they are constantly trying to catch up. At the same time, if ER interns receive too much special treatment, they may become incapacitated and less independent, as well as feel cosseted. How to achieve this balance may be difficult to know without more experience, but his reflection is in line with Murphy and Eadie's (2019) conclusion that bespoke practices and a person-centric perspective is important to achieve social value. How to actually achieve that is however still unclear. What is clear from the findings is the perception that value is created, both for the ER interns, the individual supervisors, for the work teams and for the project as a whole. This suggests that social procurement can serve as a value-adding function and service in the sector (cf. Kurdve and de Goey 2017).

Having said that, although some practices should be bespoke, some practices could benefit from being routinized for an effective use of employment requirements. Firstly, routines relating to government bureaucracy in terms of how to handle compensation issues should be improved, starting with increasing the knowledge thereof. This is in line with previous research on social procurement, where authors (Zuo *et al.,* 2012; Barraket *et al.,* 2016; Loosemore 2016) have pointed to a general lack of knowledge about social procurement, which can relate to e.g. compensation schemes for ER interns.

Secondly, routines relating to follow-up of the ER interns would not only help mitigate problems of lack of evaluation of social procurement like found in previous research (Erridge 2007; Walker and Brammer 2009; Barraket *et al.,* 2016; Loosemore 2016), but would also benefit the supervisors, who rarely get feedback on what happens to their ER interns after the internship ended, and are unsure of the long-term effect of their work. Perhaps Erridge's (2007) findings that many employed through employment requirements maintain sustained employment can be an indicator that ER interns in Sweden may have the same opportunities.

Lastly, routines on how to handle tasks that formally go beyond supervisory tasks, like helping to pay bills and read emails, should be put in place. Since supervisors are sometimes the principal Swedish contact person for (newly immigrated) ER interns, their formal work tasks and resources to perform those tasks may need to become widened to also include non-work-related issues. If the ultimate goal of employment requirements is permanent employment and increased integration, widening of supervisory responsibilities seems pertinent. Establishing these routines would however suggest an increase in administrative burden, contradicting Erridge's (2007) findings. As of today, many of the tasks undertaken by the supervisors of the ER interns may traditionally have been performed by social worker or the like. Thus, the role of supervisors and construction practitioners change when using employment requirements. Such extra-curricular tasks point to a need for extra resources, especially in terms of time, thereby potentially leading to increased costs, something which previous studies (Erridge 2007; Walker and Brammer, 2009; Zuo *et al.,* 2012;

Eadie and Rafferty 2014; Barraket *et al.,* 2016; Loosemore 2016) have shown is a concern in the construction sector.

CONCLUSION

This paper adds to previous research by providing details for how social procurement and employment requirements unfold in practice, and what effects this has for construction practitioners, ER interns, and individual projects and organizations. For construction practitioners, this entails new demands on themselves as "receivers" of the ER interns, which in turn require personal engagement in the interns and their private lives. At the same time, there are uncertainties on what this means in the long-run for the ER interns and society. For the ER interns, they are faced with demands from their supervisors on how they should engage in their internship, while at the same time they may become overexposed in advertisement purposes if they perform well. For projects, many barriers to the effective use of employment requirements were identified, especially in terms of language barriers, safety issues and how projects are structured. Also, even though many barriers exist, ER interns are expected to perform tasks like anybody else. Lastly, although employment requirements are difficult to implement, ER interns add value to a larger system outside of the individual project and organization, both in terms of increased team spirit among project members, and for adding value to the work life of individual supervisors.

Future research could build on these findings by looking into what resources and formal processes are created in order to implement employment requirements and employ ER interns: What is needed and what is lacking in projects today in order to facilitate the increased use of employment requirements? Future research could also investigate how expectations and plans for employment requirements in central organizations and amongst clients align with how they actually work in practice. Further, as there is scarce research in how social procurement works in practice in construction organizations and individual projects, future research could look into nascent research field on migrant workers, interns, and corporate social responsibility. In addition, a limitation of this study is its focus on western countries, therefore, studies on social procurement practice from other contexts are most welcome.

REFERENCES

Barraket, J, Keast, R and Furneaux, C (2016) *Social Procurement and New Public Governance*, New York: Routledge.

Dubois, A and Gadde L-E (2002) The construction industry as a loosely coupled system: implications for productivity and innovation. *Construction Management and Economics*, 20(**7**)**,** 621-631.

Eadie, R and Rafferty, S (2014) Do corporate social responsibility clauses work? A contractor perspective, *International Journal of Procurement Management*, 7(**1**), 19-34.

Edmondson, A C and McManus, S E (2007) Methodological fit in management field research, *Academy of Management Review*, 32(**4**), 1155-1179.

Enochsson, P and Andersson, T (2016) *Slutsatser Och Förslag På Åtgärder För Att Säkerställa Tillräcklig Arbetskraftskapacitet Inom Byggsektorn (Conclusions and Suggestions for Measures for Ensuring Sufficient Labour Capacity Within the Construction Sector) (N2016/05027/PUB)*. Available from Goo.gl/m4fqrY [Accessed 7 Dec 2017].

Erridge, A (2007) Public procurement, public value and the Northern Ireland unemployment pilot project, *Public Administration*, 85(**4**), 1023-1043.

Kurdve, M and de Goey, H (2017) Can social sustainability values be incorporated in a product service system for temporary public building modules*? Procedia CIRP*, 64, 193-198.

Kvale, S (2007) *Doing Interviews*. London: SAGE Publications.

Loader, K (2013) Is public procurement a successful small business support policy? A review of the evidence, *Environment and Planning C: Government and Policy*, 31(**1**), 39-55.

Loosemore, M (2016) Social procurement in UK construction projects, *International Journal of Project Management*, 34(**2**), 133-144.

Loosemore, M and Denny-Smith, G (2016) Barriers to Indigenous Enterprise in the Australian Construction Industry, *In*: Chan, PW and Neilson, CJ (Eds.), *Proceedings of the 32nd Annual ARCOM Conference*, 5-7 September 2016, Manchester, UK Association of Researchers in Construction Management, 667-676.

McCrudden, C (2004) Using public procurement to achieve social outcomes, *Natural Resources Forum*, 28(**4**) 257-67.

Montalban-Domingo, L, Garcia-Segura, T, Sanz, MA and Pellicer, E (2019) Social sustainability in delivery and procurement of public construction contracts. *Journal of Management in Engineering*, 35(**2**), 04018065.

Murphy, M and Eadie, R (2019) Socially responsible procurement: A service innovation for generating employment in construction, *Built Environment Project and Asset Management*, 9(**1**), 138-152.

Petersen, D (2018) *Let the Right Ones in? Employment Requirements in Swedish Construction Procurement*. Gothenburg: Chalmers University of Technology.

Silverman, D (2013) *Doing Qualitative Research: A Practical Handbook*. London: Sage.

Sutherland, V, McTier, A, Glass, A and McGregor, A (2015) *Analysis of the Impact and Value of Community Benefit Clauses in Procurement*. University of Glasgow Training and Employment Research Unit. Available from Goo.gl/JVAYJQ [Accessed 15 Dec 2017].

Sävfenberg, E (2017) *Ska Reda Ut Krav På Sysselsättning I Upphandlingar (Will Straighten Out Employment Requirements in Procurement) Upphandling24* Available from Goo.gl/JbePNu [Accessed 7 Dec 2017].

Troje, D and Kadefors, A (2018) Employment requirements in Swedish construction procurement: Institutional perspectives. *Journal of Facilities Management*, 16(**3**) 284-298.

Troje, D and Gluch, P (2019) Populating the social realm: New roles arising from social procurement, *Construction Management and Economics*. DOI: 10.1080/01446193.2019.1597273

Walker, H and Brammer, S (2009) Sustainable procurement in the United Kingdom public sector, *Supply Chain Management: An International Journal*, 14(**2**), 128-137.

Walker, H and Preuss, L (2008) Fostering sustainability through sourcing from small businesses: Public sector perspectives, *Journal of Cleaner Production*, 16(**15**), 1600-1609.

Zuo, J, Jin, X-H and Flynn, L (2012) Social sustainability in construction - An explorative study, *International Journal of Construction Management*, 12(**2**), 51-63.

CHALLENGES AND CRITICAL SUCCESS FACTORS FOR THE DESIGN PHASE IN SWEDISH INDUSTRIALISED HOUSE BUILDING

Shamnath Thajudeen[1], Martin Lennartsson[2] and Fredrik Elgh[3]

[1&3] *Department of Industrial Product Development, Production and Design, School of Engineering, Jönköping University, Gjuterigatan 5, 55318 Jönköping, Sweden*

[2] *Department of Building Engineering and Lighting Science, School of Engineering, Jönköping University, Gjuterigatan 5, 55318 Jönköping, Sweden*

The house building industry has been characterised as less productive compared to manufacturing industry with numerous and challenging activities including a complex integration process. For the last 20 years, industrialised house building has gained increased research and industry attention and is identified as a potential way to improve the overall house building productivity. In the overall process, the design phase has been identified as the bottleneck with several disciplines which have to be coordinated to generate a design solution that meets various customer and market requirements. Many aspects of a building's performance depend on the decisions taken in the early design process. These decisions can have a substantial impact on the overall design, lead time, cost and quality of the final product. However, there are many other important factors which need to be considered by designers during the design phase. Less attention has been paid to the identification of these factors within the design phase of the industrialised house building. Thus, the main purpose of this paper is to identify challenges and outline the critical success factors to be considered in the design phase of Swedish industrialised house building. Qualitative research was conducted in combination with literature reviews and multiple case studies linking three Swedish house building companies. Empirical data were gathered from 20 semi-structured interviews. The study identified common challenges in the house building industry and 20 critical factors that should be addressed in the design phase from both literature and practitioners view. The result shows that fixed production is crucial for identifying the critical factors rather than a building system. Also, many challenges identified from this study could be managed by developing a platform-based approach with support tools and methods for critical factors in the design phase.

Keywords: design challenges, industrialised house building, off-site construction

INTRODUCTION

The house building industry has been characterised as less productive compared to manufacturing industry with challenging and numerous activities including complex integration process (Haller *et al.,* 2015; Johnsson, 2013). The researchers and practitioners argue that productivity could be improved by implementing methods applied in other disciplines, and by increasing the industrialization in design and production (Larsson *et al.,* 2013). For the last twenty years, Industrialised House Building (IHB) has gained increased research and industry attention (Lessing, 2015;

[1] shamnath.thajudeen@ju.se

Thajudeen, S, Lennartsson, M and Elgh, F (2019) Challenges and Critical Success Factors for the Design Phase in Swedish Industrialised House Building *In:* Gorse, C and Neilson, C J (Eds) *Proceedings of the 35th Annual ARCOM Conference,* 2-4 September 2019, Leeds, UK, Association of Researchers in Construction Management, 34-43.

Viklund, 2017) and has been identified as a way to improve productivity (Lessing, 2017) in terms of quality, cost-effectiveness, safety, productivity and waste reduction. The definition of IHB, according to Lessing (2015) is "a thoroughly developed building process with a well-suited organization for efficient management, preparation and control of included activities, flows, resources and results for which highly developed components are used in order to create maximum customer value". The design is the most time-consuming phase of the IHB processes (Haller *et al.,* 2015) and the bottleneck for further streamlining the process at most house building companies (Jansson *et al.,* 2008; Söderholm, 2010). A problem in IHB is the systematic enhancement and management of the design process (Haller *et al.,* 2015) and it has become a crucial part of the house building process with high demands on timely and exact deliveries (Jansson, 2013). For IHB design work, it is essential to have a robust building system (BS) to manage the process and related flows to improve efficiency (Johnsson, 2013). Also, the sub-processes need support from tools and methods to facilitate the flow through the process and to allow parallel projects in the design phase (Jansson, 2013).

The improvement studies in the house building industry are few and there are requirements to be analysed from the viewpoint of unique products in a repetitive process (Söderholm, 2010). Even though the size of production is less compared to disciplines such as automotive and electronics, there are many commonalities in the process of IHB. Many aspects of a building's performance depend on the decisions taken early, in the design process (Viklund, 2017). It is challenging for designers to fulfil volatile demands from the stakeholders and take solid decisions, which risk impacting overall design, lead time, cost and quality of the final product.

Still, there are other critical factors apart from the time, cost and quality (Iron triangle) factors which need to be addressed in the design phase. In general, several studies from Swedish context (Gerth et al.,2013; Hjort *et al.,* 2014; Lessing, J., and Brege, S.,2015) and from international (Chan *et al.,* 2004; Halttula *et al.,* 2017; Yong and Mustaffa, 2017) have identified critical success factors in the construction sector. However, for IHB, a comprehensive investigation of critical factors that should be considered explicitly in the design phase is fewer. With the increased complexity in IHB projects, practitioners and researchers alike may find it useful to characterise the critical factors in the design phase of IHB. Thus, the purpose of this paper is to identify challenges and outline the critical factors to be considered in the design phase of Swedish industrialised house building. The scope is delimited to the design phase of IHB and the study has been conducted at Swedish house building companies using a building system based on timber frames.

RESEARCH METHODOLOGY

For this study, Design Research Methodology (DRM) was used (Blessing *et al.,* 2009). DRM is a four-stage iterative process used for conducting research in the engineering design field to develop innovative solutions that solve practical problems and allows a theoretical contribution. Figure 1 shows an overview of the research method that has been applied in this work for the two initial phases of DRM, research clarification and descriptive study I. The study was qualitative combining literature survey and multiple case studies (Yin, 1994) linking three house-building companies in Sweden.

The unit of analysis was the design phase of Swedish IHB. For the literature survey, articles that discussed the challenges and critical success factors in the house building

process were selected. Scopus was used as the database to search for the related articles. The articles were then selected according to their abstract content and the search was mostly narrowed to papers that present and examined the scope of study.

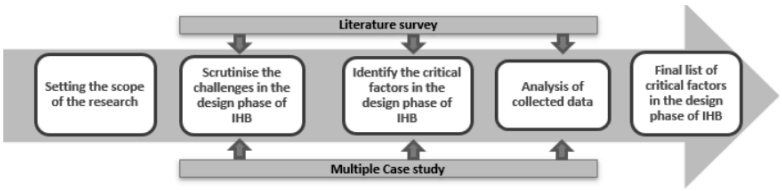


Figure 1: Research Method

The interviews of the multiple case studies were semi-structured in-depth interviews. Participants were requested to answer based on personal experiences. The scope was set with the focus on the design phase of IHB. Interview questions were focused on the existing challenges and critical success factors for the design process. Interviews were recorded and transcribed, and a qualitative data analysis was performed based on (Miles *et al.,* 1994). The transcribed data was inductively analysed for each case company. The analyse started with data reduction to bring out the specific parts of answers from each participant. The coded data from all the respondents were then sorted into specific topic. The empirical data were analysed to the existing literature regarding the challenges and critical factors in house building design. Following the data analysis, the list of critical factors was framed out by shortlisting the existing critical factors from literature and factors that should be considered in the design phase of IHB from a practitioner's perspective (empirical data).

Theoretical Background

Challenges in the design phase

Industrialised housing design is a combination of product development and preparation for production (Söderholm, 2010). Planning and coordination of the design task in IHB is a bottleneck to increasing the process flow (ibid). In the early stages of design processes, it is key to keep close communication with the customer regarding solutions and alternatives (Mukkavaara, 2018). The problem for IHB design is to bridge over from customer demands with project-specific limitations, to design solutions that create value for the customer by using a building system (Jansson, 2010). A building system for industrialised construction is defined as the collected experience and knowledge of how to realise a construction project (Söderholm, 2010).

Persson *et al.,* (2009) identified problems related to information management in industrialized house design and manufacture. The building design process generates huge amounts of information, and time is often wasted searching for, sharing and reconstructing information. One reason could be the lack of inter-operability between software used in the various stages of the building process (ibid). The building industry also suffers from the lack of supporting tools for managing regulations and client requirements in the design of buildings (Jansson, 2010). Jansson (2008) discussed the regulations from authorities challenge to deal with to get the passive house technique into a large-scale production and the local authorities tend to misinterpret IHB´s current building guidelines adding to further delays in approval. The lack of product documentation, defined processes and IT support was identified as obstacles to effective off-site house building (Hjort *et al.,* 2014). Also, lack of

standards and processes for sharing knowledge and inability to acquired experiences from already finished projects is potential source of low quality and high cost in construction (Gerth *et al.,* 2013). Andersson *et al.,* (2017) identified problems of information exchange and lack of common standards in the IHB. Design work that transforms requirements into design parameters become challenging when balancing creative and repetitive work in a partly predefined supply chain (Larsson *et al.,* 2013) and product platform approach could be a path forward to address these issues in IHB (Jansson, 2013). Many previous research studies have discussed challenges from both traditional and IHB process and very few studies have presented a comprehensive list of challenges particularly in the design phase from an industrial perspective.

Critical success factors in the design phase

Critical success factors (CSF) according to Rockart (1980), can be defined as those relatively small numbers of truly important matters, which make the difference between success and failure. There are various terminologies found in literature such as CSF, project success criteria's (PSC), success factors (SF), project success (PS) depends on different context of study. According to Chan and Chan, (2004); Yong and Mustaffa (2017), study of critical success factors is considered to be a means to improve the effectiveness of processes in the project.

Critical success factors from Swedish building industry was discussed by Gerth *et al.,* (2013) where customer segment and needs, product type, function requirements, quality, production methods were identified as key factors. They emphasize the importance of capturing production experiences and using it efficient during the design. Architectural inputs, according to (Viklund, 2017) is important to consider and prioritize when designing. Flexibility and ability to cope with variations were key factors for the NCC Komplett (Gerth 2008). This building system was developed to handle various projects according to the needs from customers and architects. Lessing, J., and Brege, S. (2015) studied the success factors of product-oriented business model from Swedish house builders named BoKlok and Kärnhem and discussed the critical factors. The cost aspects were considered most for the concept's development and other factors such as market demands, material, environment, customer priorities, quality, functional aspects were considered as central. Integration of whole value chain was one of the main keys to success for BoKlok (ibid).

From an international view, the primitive factors such as time, cost, quality and safety factors have been addressed by many researchers (Chan and Chan, 2004; Halttula *et al.,* 2017; Yong and Mustaffa, 2017) as general CSF. Also, factors such as flexibility, environmental aspects, manufacturing and assembly were mentioned by Halttula *et al.,* (2017) and legal regulations by Yuan *et al.,* (2018). Yong and Mustaffa (2017) identified the management, technology and environment aspects in construction projects. Yuan *et al.,* (2018) recently conducted a study on design for manufacturing and assembly (DFMA) approach in IHB design. Alkahlan (2016) maps the design and modular house building processes and discussed the importance of manufacturing, assembly, transportation and producibility factors.

The literature survey from past research on the topic of critical success factors from both Swedish and international was conducted. However, few publications explicitly focus on the over-arching list of design related factors in IHB. From the review of literature; time, cost, quality and safety are the four most commonly cited critical factors. The review concludes that little attention has been paid in the area of IHB which addresses the critical success factors in the design phase. Also, less studies

have been made for identifying the critical factors to be considered in the design phase of IHB. Thus, the presented research fills this gap by thoroughly examining all critical factors from practise that should be considered while making decisions in the design.

Multiple Case Study: Swedish House Builders

Three Swedish house building companies (Table 1) with prefabrication strategies using timber frame building systems were selected for the multiple case studies. Company A works on a project-based practice and company B and C have a process-based method.

Table 1: An overview of case companies

	Company A	Company B	Company C
Business area	Multi-family	Single-family	Single & multi-family
Building system	Post and beam	Panel element	Volume & Panel elem.
Customer	B2B	B2C	B2C
Contract	Supplier	Turnkey	Turnkey
Projects per year	10-12 projects	500 houses	1,500 houses
Total lead time	25-30 weeks	35-40 weeks	35-40 weeks
No. employees	140	252	1,000
Turnover	27 M€	107 M€	300 M€
Interviewed respondents	Managing Dir., Design Manager, Prod. Manager, Prod. Team lead, Design Engineer & Struct. engineer	Design Manager, Prod Manager, Prod. Dev., Tech. Manager, Market person and Design engineer.	Product manager, R&D Manager, Tech Manager, Design manager, Architect, Complaint Manager, Prod. developer.

RESULTS AND DISCUSSION

The data has been analysed based on two case studies and by integrating suitable references which mainly focused on two objectives.

Challenges in the Design Phase

One of the objectives of the study was to explore the common challenges in the house building industry from a Swedish perspective. The existing challenges in different stages of the design phase from the three case companies are presented in Table 2. Customization and distinctiveness in product have been identified as a common challenge (Jansson, 2010) for all three case companies where customer demands are outside of the building system. There is a trade-off in managing customization and at the same time utilizing production efficiently (Lessing, J and Brege, S., 2015). A CAD-engineer at company A states *"The technical detailing of connectors used in the interfaces of the building remains as a challenge as new connectors have been designed in every project"*. Lack of clarity about product assortment was raised by some participants where salespeople are facing difficulties in explaining it to the customers. The salesperson should have proper knowledge and be aware of the product offer and be updated about the fundaments of the BS (Söderholm, 2010). Late design changes (Haller *et al.,* 2015) were mentioned by the participants from all companies, but in order to avoid delays these are reduced by implementing gate system in the design.

All companies have included the standards for technical and functional details within their building system, but it has not been accurately followed by other stakeholders involved. All companies highlighted poor information flow (Hjort *et al.,* 2014) when

more actors are involved, e.g. digital transfer is missing between the architect and structural engineer, which results in loss of customer specific information. Common for all companies is that the major components of the building are designed in-house, while building services (HVAC, plumbing and electricity) are designed mainly by external consultants. Consequently, drawing quality is reduced and information is lost in the transfer between systems (Persson *et al.,* 2009). In order to improve the design efficiency, company B has started to do all detailing in-house. Every time consultant makes changes, it can yield rework and waste that could leads to projects get delayed.

Table 2: Main challenges in the design phase articulated by the respondents

No.	Company A	Company B	Company C
1	Uniqueness in technical and functional needs from the architect and customers which lies outside the company`s BS	Customer needs for open spaces and more windows conflict with struct. design. Architect does not follow BS	Customization and develop solutions from existing the components. Fulfil demands and keep internal efficiency.
2	Late changes in design from customers results in reworks and generate wastes in process	Changes in legal regulations for energy requirement of the buildings, transportation etc.	Changes in legal regulations and late approvals, Varying market demands etc..
3	Lack of tools and checklists to plan and monitor projects.	Planning issues in managing multiple projects	Sales offers solutions outside the building system
4	Design knowledge not captured and reuse it properly	CAD and ERP systems not connected	Employee turnover and documentation of knowledge
5	Poor information flow among stakeholders and issues with communication.	Rework & issues related to information exchange/loss while updating several times	Poor information flow among stakeholders, e.g., between sales & design
6	Clash issues among installation drawings in CAD model.	Clash issues due to consultant's CAD software not working	Clash issues due to consultant's CAD software not working
7	Tools for final evaluation of drawings and details missing	Additional drawings requirements from customers	Long lead time for some components e.g. Windows
8	No formal system to collect and analyse the customer feedback	As-built drawings not updated due to poor feedback from site.	Inflexible due to fixed production and clash issues during installation works
9	No checkpoint to validate and confirm late customer changes	Cultural resistance to move towards digital way of working.	Cultural resistance to move towards digital way of working.

In general, governmental regulations were considered as a barrier for the house building industry which was also pointed out by Larsson *et al.,* (2013). There is also a conflict recognized between what the customer wants and what the companies can deliver as the predefined solutions are linked with regulations and production flexibility (Gerth *et al.,* 2013). R&D manager from company C stated that *"The latest rules create difficulties for the wall elements production because the facility is not flexible enough"*. Thus, the company needs to revaluate how to manufacture the components. Another issue for all companies was the misalignment between CAD-models and interface of production equipment, e.g. CNC-machinery (nailing machine etc.) cannot read the CAD-file format. The absence of geometrical standards results in losing data clarity while transferring information between systems. Thus, a more advanced approach for dealing the information and synchronization between CAD models and the necessary production data could be developed (Andersson and Lessing, 2017). As Malmgren *et al.,* (2010) addressed, formalization of tactic knowledge is still lacking in case companies and it has been acknowledged as a common barrier. Lot of efforts has been made to improve the general level of maturity in IT systems. Though, all companies have developed a building system which is regarded as a technical platform for product development. The BS has the

capacity to manage most of the challenges identified, but the way of working is not structured enough currently.

Aggregation and Discussion of Critical Success Factors in the Design Phase

The other objective was to identify the factors that are critical for the design process. An aggregation of critical factors that should be considered in the different design phases has been listed in Table 3. The possible connection between the critical factors and the challenges identified is shown. Also, the source of data collected is presented whether the factors identified from literature review or case companies in order to ease the analysis of data and give a clear picture for readers.

The literature review conveys that many researchers have shown concern in the topic of critical success factors in construction over the past years. However, for the design phase in IHB, this topic has not been fully investigated. Traditionally, to measure the project outcome, success factors such as time, cost, and quality have been used. Still, in IHB many other aspects need to be addressed. The identified critical factors from this study are broad in nature and can have single or multi-dimensional views, e.g. cost factor is measurable while transportation factor has different dimensions and could be evaluated in many ways and it varies depend on the context of the company. From an industrial view, it is important to select few critical factors out of the list and develop support for those factors since it depends on individual production settings. From company A, time, cost, manufacturability and assembly factors was identified as most critical where manufacturability, assembly, cost and customer requirements from company B and manufacturability, assembly, customer requirement and regulations from C. Flexibility aspect was stated by many participants to offer high variants for customers. However, it was one of the reasons for the failure of NCC Komplett concept (Gerth 2008) and a balanced flexibility is important to consider. Lately, the critical factors have shifted from the common time, cost and quality aspects to a broader list of critical factors (Halttula *et al.,* 2017). The challenges and CF are connected (table 3) in such a way that any support developed for these factors could benefit to reduce the intensity of challenges. This aligns with (Gerth *et al.,* 2013) where a cyclic nature of improvement processes is relevant for housing by using experiences from previous projects and develop support for critical factors at the same time.

From the cases, a partial alignment between CSF and challenges has been identified where some existing support has been developed within the design process to mitigate the earlier challenges and participants acknowledged the same during the discussion e.g.: stage gate in design reduced the late design changes. The difference between traditional construction and IHB is that the IHB companies possess a partially fixed production where companies made large investments, which they aim at utilizing as much as possible, i.e. IHB is production-oriented and process-based (Johnsson, 2013; Hjort *et al.,* 2014) compared to traditional construction being more resource-based and they are evaluating success according to the time, cost and quality factors. It was a question in the beginning that if the building system could make an impact in identifying the critical factors. This was examined by case selection where companies are working with different building systems. Thus, the BS is not an element for identifying the critical factors and independent to each other. Rather, the setting of the fixed production facility is more important than the building system. It could vary in terms of different production settings and BS has been designed according to the

production settings. However, currently companies are not getting the full potential of BS.

Table 3: Critical success factors in the design phase and connection to challenges. Phase: Overall (O), Conceptual (C), System level (S), Detailed (D); Challenge: Table 2 (1-9), Source: Literature (L), Company A-C (A, B, C)

Critical factors	Description	Phase	Challenge	Source
Lead time	Time associated with different process	O	All	L, A, B, C
Cost	Cost associated with different process	O	All	L, A, B, C
Quality	Quality associated with different process	O	All	L, A, B, C
Market demands	Consideration of changing demands from different markets during the design	C	C2, C3	B, C
Customer requirements	Fluctuating and exclusive requirements	C, S	A1, B1, C1	L, A, B, C
Legal regulations	Legislations and policies from local and central municipalities	C, S	B2, C3	L, B, C
Environmental aspects	Design parameters specific for different regions, sustainability focus etc.	C, S	B2, C2	L, B, C
Cost effective materials	Cost decisions to select material and fulfil internal & external needs	C, S	B2, C2	B, C
Structural aspects	Including robust structural design to fit building function	S, D	A1, B1, C5	L, A, B, C
Technical & Functional requirements	Fulfilling technical specification, detailing and functional requirement to meet customer demands	O	A1, B1, A5, C5, A9	L, A, B, C
Flexibility	Flexibility in design strategies to meet changes for building components	O	A2, C8	L
Re-usability	Include re-usable material in building components and structures design	C, S	A4, C4	L
Modularity	Plan for modular design of component to ease prefabrication process	S, D	A1, A7	L, A, B, C
Production infl. design	Channel to exchange knowledge between people from production to designers.	S, D	A5, B8, C8	B
Manufacturing	A design approach that utilise the capability of fixed production and its constraints	O	A1, B1, C1, C7, B7, C8	L, A, B, C
Producibility	Ensure the functional properties of building and efficient production of components	S, D	A1, B1, A5, B5, A6, B6	L, A
Transportation	Approach focusing on efficient transportation of building components	S, D	B2	L, A, B, C
Safety	Safe design plans reducing risk during production and on-site assembly	O		L, A, B, C
Assembly & Installation	A design approach that focuses on efficient assembly and Installation at the site	S, D	A6, B6, C6, B8, C8	L, A, B, C
Disassembly	Approach focusing on dismantling strategies of building components during early design	S, D	A4, C4	L, A

Manufacturability and assembly factors are less highlighted in traditional construction (Alkahlan, 2016) where it is more emphasised in IHB and also from the interviews. The respondents highlighted these factors but did not express the DFMA approach clearly, which means that they are not fully aware of it. Companies refer BS as their support but, it has not been adapted to deal with these issues and does not have adequate support for this approach. It is important to have dedicated support for these factors. From an engineering design perspective, companies should work with platform based DFMA approach to be successful in the design process regarding the

outcome even though it has different dimensions (Yuan *et al.,* ,2018; Jansson, 2013). The main purpose of having DFMA is to improve manufacturability. Moreover, DFMA is an approach to reduce cost and lead time, increase quality and safety (Gerth *et al.,* 2013). The analysis points out that the manufacturability and assembly factors were acknowledged as most critical, common for all companies. To conclude, most of the factors identified, correspond to the recognized factors from literature.

CONCLUSIONS

This paper presents the preliminary findings aimed at supporting and improving the design process of the industrialised house building industry and makes two key contributions. Firstly, the common challenges faced by the housing industry were discussed from both literature and practitioner's perspectives. Secondly, the study has identified twenty critical factors that should be addressed in the conceptual, system and detailed design of IHB have been presented. The paper points out the importance of considering critical factors which have been retained as a research gap so far in the industry. The study indicates that the challenges and critical factors are not unique or specific to a certain company. Rather, it is a general issue for the IHB industry. All decisions made during design has an impact on the rest of the process where these factors should be considered. In order to achieve higher efficiency in the design phase, IHB companies rigorously need supporting tools and methods for these critical factors that improves their technical and process platform (Jansson, 2013). Thus, the challenges identified could be managed eventually and helps to develop a robust building system with better process control to meet market demands. The result also shows that fixed production is more crucial for identifying the critical success factors. International generalizations should be made with caution, as the empirical findings are based on Swedish practitioners. These findings will serve as a base for future studies and an investigation of different critical factors and the development of support for those factors should be considered.

REFERENCES

Alkahlan, B S (2016) *Integrated Design and Manufacturing [IDM] Framework for the Modular Construction Industry*. Virginia Tech.

Andersson, N and Lessing, J (2017) The Interface between industrialized and project-based construction, *Procedia Engineering*, 196, 220-227.

Blessing, L T and Chakrabarti, A (2009) *DRM: A Design Research Methodology*. London: Springer.

Chan, A P and Chan, A P (2004) Key performance indicators for measuring construction success, *Benchmarking: An International Journal*, 11(**2**), 203-221.

Gerth, R, Boqvist, A, Bjelkemyr, M and Lindberg, B (2013) Design for construction: Utilizing production experiences in development, *Construction Management and Economics*, 31(**2**), 135-150.

Gerth, R (2008) *En Företagsmodell För Industriellt Byggande (An Enterprise Model for Industrial Construction)*. Licentiatavhandling i Industriell Produktion, Kungliga Tekniska Högskolan, Stockholm, Sweden.

Haller, M, Lu, W, Stehn, L and Jansson, G (2015) An indicator for superfluous iteration in offsite building design processes, *Architectural Engineering and Design Management*, 11(**5**), 360-375.

Halttula, H, Haapasalo, H, Aapaoja, A and Manninen, S (2017) Early involvement and integration in construction projects: The benefits of DfX in elimination of wastes, *International Journal of Management, Knowledge and Learning*, 6(**2**), 215-237.

Hjort, B, Lindgren, J, Larsson, B and Emmitt, S (2014) Success factors related to industrialized building in Sweden. *In*: *CIB International Conference on Construction in a Changing World*, 4-7 May, Heritance Kandalama, Sri Lanka

Jansson, U (2008) *Passive Houses in Sweden*. Lunds Tekniska Högskola, Energi och Byggnadsdesign EBD.

Jansson, G (2013) *Platforms in Industrialised House-Building*. Luleå: Luleå tek universitet.

Jansson, G, Söderholm, E and Johnsson, H (2008) Design process organisation at industrial house builders: A case study of two timber housing companies in Sweden. *In:* Dainty, A (Ed.), *Proceedings of the 24th Annual ARCOM Conference*, 1-3 September 2008, Cardiff, UK. Association of Researchers in Construction Management, Vol. 1, 135-44.

Johnsson, H (2013) Production strategies for pre-engineering in house-building: Exploring product development platforms, *Construction Management and Economics*, 31(**9**), 941-958.

Larsson, J, Eriksson, P E, Olofsson, T and Simonsson, P (2013) Industrialized construction in the Swedish infrastructure sector: Core elements and barriers, *Construction Management and Economics*, 32(4), 83-96.

Lessing, J (2015) *Industrialised House-Building-Conceptual Orientation and Strategic Perspectives*. PhD Thesis, Lund University, Lund.

Lessing, J and Brege, S (2015) Business models for product-oriented house-building companies-experience from two Swedish case studies, *Construction Innovation*, 15(**4**), 449-472.

Malmgren, L, Jensen, P and Olofsson, T (2010) Product modelling of configurable building systems - A case study. *Journal of Information Technology in Construction*, 15, 354-368.

Miles, M B and Huberman, A M (1994) *Qualitative Data Analysis: An Expanded Sourcebook*. London: Sage.

Mukkavaara, J (2018) *Structures for Supporting BIM-Based Automation in the Design Process*. Licentiate Thesis, Luleå University of Technology.

Rockart, J F (1980) *The Changing Role of the Information Systems Executive: A Critical Success Factors Perspective*. Working Paper 1297-82, Sloan School of Management, Massachusetts Institute of Technology,

Persson, S, Malmgren, L and Jonsson, H (2009) Information management in industrial housing design and manufacture, *Journal of Information Technology in Construction*, 14, 110-122.

Söderholm, E (2010) *Applicability of Continuous Improvements in Industrialised Construction Design Process*. Licentiate Thesis**,** Luleå tekniska universitet.

Viklund, E (2017) Design approaches in industrialized house building: A creativity perspective: Ett kreativitetsperspektiv (Thesis).

Yong, Y C and Mustaffa, N E (2017) Critical success factors for Malaysian construction projects: An investigative review, *International Journal of Built Environment and Sustainability*, 4(**2**).

Yuan, Z, Sun, C and Wang, Y (2018) Design for manufacture and assembly-oriented parametric design of prefabricated buildings, *Automation in Construction*, 88, 13-22.

AN ASSESSMENT OF RISK FACTORS IMPACTING BUDGET VARIABILITY IN NEW ZEALAND COMMERCIAL CONSTRUCTION PROJECTS

Johnson Adafin[1], James O B Rotimi[2], Suzanne Wilkinson[3] and Jasper Mbachu[4]

[1] *School of Building Construction, Unitec Institute of Technology, Auckland, New Zealand*

[2&3] *School of Construction and Built Environment, Massey University, Albany, Auckland 0745, New Zealand*

[4] *Faculty of Society and Design, Construction Management and Quantity Surveying Programme, Bond University, QLD 4229, Australia*

A review of several authors shows that various risk factors abound which potentially impact on the outturn tender sums (OTS) of construction projects from the design-stage elemental cost plans (ECPs)/budget estimates. Proper risk analysis could at least partially solve this problem, by lowering the variation between the design-stage ECPs and their OTS. The concern of the current study is the variability between design-stage ECP and OTS, whereas the conjecture is that risk could be responsible for the observed variability. Empirical data was obtained from 208 practising New Zealand (NZ) construction consultants through an online survey. A quantitative analysis was performed to determine the most critical risk factors that impact ECPs. Findings revealed variation between ECPs and OTS (inflated risks) within the region of +1% and 23.86%. These verify discrepancies in the budgeted costs of commercial projects at preconstruction phase, and the risk factors responsible should be the initial focus of construction project consultants. The research provides invaluable insights from practice that could propose and strengthen the development of an effective mitigation strategy by using risk management approach which promotes risk/cost management integration in project delivery for the construction industry. This study therefore attempts to influence government policy to develop support mechanisms to encourage effective risk management practice in the construction industry in NZ.

Keywords: budget overrun, elemental cost plan, New Zealand, out-turn tender sum

INTRODUCTION

The construction industry in New Zealand (NZ) is of paramount importance for employment and economic growth. While MBIE (2014) claimed that it contributes about 6.3% to the gross domestic product (GDP) and represents over 40% of the national budget revenue; PWC (2011) affirmed that construction accounts for more than 8% of employment creation and an average of 50% of the gross fixed capital formation (GCFC). This makes the industry a significant driver of economic growth. Therefore, efforts directed towards revamping construction efficiency by means of cost-effectiveness, timeliness and quality standard would be beneficial as this obviously contributes to cost savings for the country. Cost as one of the measures of overall success (Ameyaw *et al.,* 2015) seems most significant, owing to its direct financial

[1] jada393@aucklanduni.ac.nz

Adafin, J, Rotimi, J O B, Wilkinson, S and Mbachu, J (2019) An Assessment of Risk Factors Impacting Budget Variability in New Zealand Commercial Construction Projects *In:* Gorse, C and Neilson, C J (Eds) *Proceedings of the 35th Annual ARCOM Conference,* 2-4 September 2019, Leeds, UK, Association of Researchers in Construction Management, 44-53.

impact on all stakeholders. It is thus noteworthy that pre-tender budgeting activities continue to pose challenges to project stakeholders.

Despite much care and effort in the preparation of design-stage ECPs, differences observed between them and OTS are usually significant (Odeyinka 2010). Deviations in the region of +1% and +12% are mentioned in Morrison (1984), Skitmore and Picken (2000) and Oladokun *et al.,* (2011). Research undertaken by Adafin *et al.,* (2015) indicated discrepancies in budgeted costs between the ECPs and OTS in the region of -14% and +16%. These are reasons behind a follow-up study that investigated the accuracy and reliability of design-stage ECP in building projects. Adafin (2017) stated that the observed variance between ECPs and OTS differ significantly, drawing inferences from a study that evaluated cost data from completed building projects in NZ. Adafin (2017) found these deviations to be significantly higher for commercial projects (-14.22% and +16.33%; Reliability [Rel.] Rank = 3), than in residential projects with small, reliable and acceptable percentage deviations (-3.67% and +3.95%; Rel. Rank = 1). Significant discrepancies are further noted in both educational (-3.98% and +12.15%; Rel. Rank = 2) and refurbishment (-10.07% and +30.14%; Rel. Rank = 4) projects (see Adafin 2017). These findings suggested that deviations occur even in developed countries with mature construction industries and established construction practices. Xia *et al.,* (2017) observed that such deviations could be due to risk factors that are inherent in both design and construction activities. Odeyinka (2010) explained that these risks are covered by allocating contingency costs to include both expected and unexpected circumstances in design-stage ECPs and tender sums. Observed variance between ECPs and OTS could be reduced, if risk items were identified and reasonably priced during design development. As evidenced in Adafin *et al.,* (2016), this study posits that budget overrun could vary with procurement and project types. Projects awarded under the traditional lump sum fixed price contracts were considered for this investigation, because of accessibility of data.

Substantive research has indicated that most studies on risk management acquired data on projects executed in the East Asia, Europe, Middle East and United States (El-Sayegh and Mansour 2015). Predominantly, the key objective is how these risk factors that are inherent in construction projects, interact to cause the variations observed between ECPs and OTS. Limited attention is known to have been given to this area in NZ, which could foster/promote industry practice. While clients are becoming uncomfortable at seeing their projects completed over-budget, this study therefore attempts to influence government policy to develop support mechanisms to foster/encourage effective risk management practice in the construction industry in NZ.

LITERATURE REVIEW

Cost Planning and Inherent Risks Impacting Budget Overrun

Jaggar *et al.,* (2002) described cost planning as the totality of processes involved in the financial management of a construction scheme during design development, so that the contractor's tender price matches the initial financial plan. Within the context of the current study, cost planning describes any means of utilising early-stage strategic cost advice in the design process to give project owners good value for money. ECP therefore portrays a basic budget and represents a final ECP amendment before tenders are invited, while OTS is the accepted tender sum or in other words, initial contract sum. The difference between ECP and OTS is the increase of cost in addition to tenderer's mark-up. In Carter et al.'s (1994) opinion, risk frequently refers to the ways in which actual results may be worse than planned. This definition reflects the views

of some early studies cited in Akintoye and MacLeod (1997). According to Akintoye and MacLeod (1997), project risk denotes "an exposure of project activities to adverse consequences of future events that affect project objectives". Risks are uncertain events or conditions that, when they occur, have positive or negative effect on a project's objectives (Akintoye and MacLeod 1997; Carter *et al.,* 1994; PMI 2008). This research embraces the view that the benefits or positive impacts of risk on project objectives could be achieved by minimising some risk occurrences and detrimental impacts. By this, this study connects with the realities of practice by viewing risk as the extent and impact of adverse occurrences that cause a project to exceed its predicted ECPs.

Several studies have identified numerous risks that influence budgetary performance of construction projects (see Akintoye 2000; Doyle and Hughes 2000; Ling and Boo 2001; Odusami and Onukwube 2008; Enshassi *et al.,* 2013; Adafin *et al.,* 2018: 2, 3 and 5). Evidence and arguments in construction management researches (Odeyinka *et al.,* 2010; Adafin *et al.,* 2018: 3; Agyekum-Mensah 2018; Love and Ahiaga-Dagbui 2018; Yap *et al.,* 2018) indicated that it is rare to find a project in which the OTS equals the budget estimate for a variety of reasons. Therefore, an effective mitigation strategy using risk management approach (a deterministic system to risk) should reduce budget/cost and schedule/time overruns on construction projects (Hwang *et al.,* 2014). Thus, as a partial solution, this research proposes to reduce the variances between ECPs and OTS during preconstruction phase, through an analysis of risks.

There is a dearth of literature and research specific to NZ's construction project risk. Furthermore, identifying and assessing risk factors for NZ construction projects, and how these interact to account for the wide variation between design-stage ECPs and OTS, will be significant. The examination of perceptions held by NZ construction consultants on risk occurrence in traditionally procured commercial construction projects has remained unexplored. The current study therefore investigates variations between ECPs and OTS in commercial projects from construction consultants' (i.e., architects, quantity surveyors [QS], and project managers [PMs]) perspectives. Questions addressed by this study include: what are the risk factors impacting variability between design-stage ECPs and OTS; and how these identified risk factors can be evaluated using Kendall's concordance, to determine the most significant?

METHODOLOGY

To address the research questions posed by the current study, a questionnaire with closed-ended questions was administered to gain more understanding of cost and risk issues, following Fellows and Liu (2008). An initial pilot study including 32 participants (i.e. NZ-based architects, QS and PMs) was conducted in line with Nworgu (2006), to ensure clarity of the questionnaire and the relevance of the risks explored to NZ commercial construction.

36 risk factors were classified into 7 main groups (see Adafin *et al.,* 2018: 3), based on literature review and expert judgment by five construction consultants (i.e. architects, QS and PMs). Using expert judgments has been extensively noted for risk identification (Kassem *et al.,* 2019). A criticality cut-off point of 3.00 (Fellows and Liu 2008) on a five-point Likert scale was employed to prioritise the top 16 critical risks from the 36 risk factors. Adafin *et al.,* (2016) suggested that risk factors, with overall mean scores of 3.00 and above, had significant impacts on variability and viewed to have potential impacts on budgetary performance of construction projects. These 16 significant factors formed the basis of a refined questionnaire administered to participants (private consultancies). Key sections in the questionnaire included: questionnaire introduction;

project-specific questions including risk factors on the observed variation (i.e. extent and impact); demographic information and, conclusion and feedback. Respondents were requested to indicate the level of importance of the categorised 16 critical risk factors using the five-point Likert scale of 1 (very low risk occurrence) to 5 (very high level of risk occurrence); and 1 (very low risk impact) to 5 (very high-risk impact). The theoretical justification for the application of the five-point scale was found in Arif *et al.,* (2015), and the two-dimensional scaling questionnaire used in this study followed Odeyinka *et al.,* (2012). Thus, the measuring scale had the property of an interval scale, which makes the collected data suitable for various statistical analyses.

A stratified random sampling approach, following Naoum (2007) was employed with the sampling frame drawn from the databases of the New Zealand Institute of Building (NZIOB), New Zealand Institute of Architects (NZIA), and New Zealand Institute of Quantity Surveyors (NZIQS) (see Table 1). 420 registered members (financially valid members), selected from the directories maintained by the Institutes, received an email from the representatives of the professional bodies in January/February 2017. The participants are reasonably well experienced and with good understanding of project-risk issues. Of these, 245 complete responses were received (see Table 1), but only 208 (sample size) of these involved traditionally procured commercial projects. The study is based on those 208 responses, which is an adequate relevant-data response rate of 65% higher than 40% suggested by Moser and Kalton (1981). The survey's demographic information included designation, work experience, and academic and professional qualifications (see Table 1). It is significant to highlight that 85% of the respondents based their views on personal experiences with traditionally procured commercial projects.

Responses to the questionnaire survey were analysed using descriptive statistics (Naoum 2007), the mean score analysis and degree of risk (Odeyinka *et al.,* 2012) and Kendall's coefficient of concordance w (Offei-Nyako *et al.,* 2016). The responses were ranked to determine the relative importance of the risk factors considered. Mean scores MS were used to determine the degree-of-risk values; whereas the "Degree of Risk" measure was used for subsequent ranking of identified risk variables. This is expressed as R = P x I, where R = the degree-of-risk, P = extent of risk occurrence, and I = the perceived impact on a project. Further, Kendall's coefficient of concordance (w) was used to measure the degree of agreement among sets of rankings in the estimation of risk factors, by the study participants.

DATA ANALYSIS AND RESULTS

Table 2 (Risk factors' means and rankings) provides a summary of the data analysis of the extent of risk occurrence and its perceived impacts, and the 'degree-of-risk' scores in commercial projects. The 'degree-of-risk' values for the combined sample range from 3.73 to 15.08. A few risk factors fall between 7.58 and 15.08, revealing the complex interaction of the most critical risk items. The resultant ranking of the 16 risk factors highlights the following top-five risk factors that could influence predictive modelling: scope change (owner's requirements), project complexity, information quality and flow requirements, availability of design information, and consultants' skills. Further to the mean ranking analysis, the study performed the Risk impacts' Kendall's concordance analysis to measure concordance of the three groups of consultants (architects, QS and PMs), from which opinions were sought. The Statistical Package for Social Sciences (SPSS) software was used for the analysis and the results presented in Table 3.

Table 1: Participants' Demographic Information

Characteristics	Number of Respondents	Percent	Cumulative Percent
Designation of Respondents			
Architect	102	41.63	41.63
Client's QS	71	28.98	70.61
Project Manager	72	29.39	100.00
Total	245	100.00	
Academic Qualification of Respondents			
PhD	4	1.63	1.63
Master's Degree	81	33.06	34.69
Bachelor's Degree	110	44.90	79.59
PGD / Graduate Diploma	21	8.57	88.16
Diploma/ND/HNC/HND	26	10.61	98.77
None	3	1.23	100.00
Total	245	100.00	
Professional Qualification of Respondents			
Fellow membership, e.g. FNZIA, FNZIQS, FNZIOB	108	44.08	44.08
Full membership, e.g. MNZIA, MNZIQS, MNZIOB	127	51.84	95.92
None	10	4.08	100.00
Total	245	100.00	
Professional Experience of Respondents			
1-10 years	16	6.53	6.53
11-20 years	46	18.78	25.31
21-30 years	93	37.96	63.27
31-40 years	67	27.35	90.62
Over 40 years	23	9.38	100.00
Total	245	100.00	
Mean = 26.93 years			

Note: QS = quantity surveyor; PhD = doctor of philosophy; PGD = postgraduate diploma; ND = national diploma; HNC = higher national certificate; HND = higher national diploma; FNZIA = fellow, New Zealand Institute of Architects; MNZIA = member (full), New Zealand Institute of Architects; FNZIQS = fellow, New Zealand Institute of Quantity Surveyors; MNZIQS = member (full), New Zealand Institute of Quantity Surveyors; FNZIOB = fellow, New Zealand Institute of Building; MNZIOB = member (full), New Zealand Institute of Building.

A Kendall's w value of 0.84 was obtained; this means that the 208 respondents significantly agreed in their assessments. The value of w = 0.84 (w is greater than 0 and close to 1) indicates a positive and strong agreement amongst the consultants in their estimation of each of the risk factors. Also, this shows that a positive/perfect concordance exists in the ranking of risk factors that affect variability between ECPs and OTS. Hence if any predictive modelling was to be undertaken, the top-five risk factors could provide reliable inputs into the model development.

From the sample population of 208 participants, a stratified sample of 12 QS provided ECPs and OTS data for this study. Table 4 shows variation between ECPs and OTS within the region of +1% and 23.86% for commercial projects. The cost data was analysed to achieve an estimated relationship between the factors and their variances. This gives a further insight into the top-five risk factors that cause variation in the budgeted costs and could be relied upon for future predictive modelling. Table 2 displays the risk factors in line with their relative importance.

The results are presented in this section, aligning with the outcome of previous studies with a focus on risks during estimating and tendering practices. Scope change was ranked 1st as observed in Table 2. This finding is consistent with some previous studies (Odeyinka *et al.,* 2010; Ameyaw *et al.,* 2015) that ranked this risk factor 2nd and 4th in the UK and Ghana respectively. This suggests that the accuracy of cost plan estimates is highly dependent on the level of details available within the project scope definition. Early (and frequent changes) in design and scope will impact budgetary performance of a commercial project at the pre-contract phase, as there seems to be some level of inevitability in design changes.

The risk factor ranked 2nd is Design and Construction complexity. Doyle and Hughes (2000) stated that the rapid development in technology affects design and construction

activities. Project complexity implies innovations, and a degree of difficulty in performing tasks. Thus, complexity in commercial design and construction is known to be significant in budget overruns. It can safely be concluded from this finding that the more complex a project is (in size, shape, height and aesthetics), the more detailed will be the design/plan of work and site production.

Table 2: Construction consultants' opinion of risk occurrence for commercial projects

		Architects (N=82)			Quantity Surveyors (N=62)			Project Managers (N=64)			Total Sample (N=208)		
Overall Rank	Risk Factors	Risk extent mean	Risk impact mean	Degree of risk	Risk extent mean	Risk impact mean	Degree of risk	Risk extent mean	Risk impact mean	Degree of risk	Overall risk extent mean	Overall risk impact mean	Overall degree of risk
1	Scope change (owner's requirements)	3.53	3.78	13.34	3.86	4.21	16.25	3.82	3.88	14.82	3.76	4.01	15.08
2	Project complexity	3.18	3.60	11.45	3.51	2.92	10.25	3.44	3.78	13.00	3.42	3.65	12.48
3	Information quality and flow requirements	3.01	3.22	9.69	3.73	3.82	14.25	3.50	3.83	13.41	3.35	3.72	12.46
4	Availability of design information	2.99	3.33	9.96	3.75	3.68	13.80	3.49	3.79	13.19	3.36	3.63	12.20
5	Consultants' skills	2.94	3.24	9.53	3.52	2.90	10.21	3.53	3.86	13.63	3.28	3.60	11.81
6	Property market condition	3.22	3.34	10.75	3.45	3.80	13.11	3.18	3.40	10.81	3.25	3.58	11.64
7	Experience of project team	2.83	2.94	8.32	2.62	2.45	6.42	3.74	3.85	14.40	3.15	3.47	10.93
8	Site condition information	2.62	3.11	8.15	2.72	2.87	7.81	3.72	3.82	14.21	3.12	3.48	10.86
9	Tender documentation	1.92	2.40	4.61	2.78	2.80	7.78	3.56	3.76	13.39	2.79	3.21	8.96
10	Extent of completion of pre-contract design	2.42	2.58	6.24	2.60	2.46	6.40	2.69	2.90	7.80	2.58	2.94	7.58
11	Provision of labour and materials	2.11	2.41	5.09	1.72	1.92	3.30	3.17	3.56	11.29	2.53	2.87	7.26
12	Project type	2.38	2.65	6.31	1.87	1.86	3.48	2.57	3.14	8.07	2.46	2.76	6.79
13	Construction method	2.05	2.46	5.04	1.82	1.78	3.24	2.56	2.88	7.37	2.25	2.69	6.05
14	Project location	2.15	2.38	5.12	1.68	1.26	2.12	2.39	2.44	5.83	2.18	2.42	5.28
15	Defective design and specification	1.65	1.88	3.10	1.62	1.60	2.59	1.68	2.56	4.30	1.92	2.31	4.44
16	Client type	1.93	2.16	4.17	1.46	1.38	2.01	2.18	1.81	3.95	1.82	2.05	3.73

The risk variable ranked 3rd by the respondents is Information quality and flow requirements. Table 2 reveals that this factor has a significant impact in NZ on the budgetary performance of commercial projects at the pre-contract phase of development process. However, it ranked 15th in Akintoye (2000) suggesting that it is less critical in the UK as cost planning practice requires the consultants to supply most of the information required for the estimating function; they influence the quality of information provided and the efficiency of flow of such information.

This variable (Availability of design information) was ranked 4th, based on the sample score. The results presented in Table 2 show that availability of design information is considered a key risk affecting cost planning accuracy in NZ and has some significant impact on the budgetary performance of commercial projects at the preconstruction phase of project development. This finding is however consistent with Ling and Boo's (2001) submission, that drawings are important for effectively communicating designer intentions for the project owner's conceptions. Therefore, project implementation strategies for collecting information on project performance are considered vital for project planning and control. This necessitates why incomplete or inadequate design information, especially as it affects quality and availability, could influence the budgetary performance of commercial projects in the pre-construction phase.

Table 3: Measuring construction consultants' agreement/disagreement using Kendall's concordance analysis

Risk Factors	Architects (N=82) rank (R_1)	Quantity Surveyors (N=62) rank (R_2)	Project Managers (N=64) rank (R_3)	**R** Sum of Ranks $R_1+R_2+R_3$	**D** (R –A)	Kendall's concordance coefficient *(w)*
Scope change (owner's requirements)	1	1	1	3	-22.5	506.25
Project complexity	2	5	8	15	-10.5	110.25
Information quality and flow requirements	5	2	5	12	-13.5	182.25
Availability of design information	4	3	7	14	-11.5	132.25
Consultants' skills	6	6	4	16	-9.5	90.25
Property market condition	3	4	10	17	-8.5	72.25
Experience of project team	7	9	2	18	-7.5	56.25
Site condition information	8	7	3	18	-7.5	56.25
Tender documentation	14	8	6	28	2.5	6.25
Extent of completion of pre-contract design	10	10	12	32	6.5	42.25
Provision of labour and materials	12	12	9	33	7.5	56.25
Project type (residential, commercial, educational, etc.)	9	11	11	31	5.5	30.25
Construction method	13	13	13	39	13.5	182.25
Project location	11	15	14	40	14.5	210.25
Defective design and specification	16	14	15	45	19.5	380.25
Client type (private, public, government, agencies, NGOs, etc.)	15	16	16	47	21.5	462.25
Total	-	-	-	408	-	2576
Mean (A)	-	-	-	25.5	-	-
W	-	-	-	-	-	0.84

Consultants' competency was also ranked 5th by the respondents. This ranking agrees with Odusami and Onukwube's (2008) and Enshassi et al.'s (2013) findings, where their respondents ranked this factor 1st and 4th, respectively. However, in Akintoye (2000), expertise of consultants was ranked 23rd out of 24 of the risk factors they evaluated. This is because project participants are usually responsible not only for providing a reasonable amount of information during design development and tender stages, but also its quality and flow.

Table 4: Estimated variation between ECPs and OTS

Case Study Project No.	ECPs (NZ$)	OTS (NZ$)	Variation	% Variation
1	31,790,000.00	35,790,100.00	4,000,100.00	12.58
2	28,245,000.00	30,285,225.00	2,040,225.00	7.22
3	3,780,100.00	3,790,200.00	10,100.00	0.27
4	1,578,317.00	1,954,865.00	376,548.20	23.8576
5	26,795,275	31,250,000	4,454,725	16.625
6	1,730,000.00	1,960,000.00	230,000.00	13.2948
7	13,000,000	15,500,000	2,500,000	19.2308
8	26,795,275	31,250,000	4,454,725	16.625
9	4,536,000.00	5,201,189.00	665,189.20	14.6647
10	1,090,000.00	1,120,000.00	30,000.00	2.7523
11	12,650,000	13,720,000	1,070,000	8.4585
12	23,500,000	27,000,000	3,500,000	14.8936

Note: ECP = elemental cost plan; OTS = out-turn tender sum; NZ$ = New Zealand dollars

It is thus apparent from this study that uncertainties and hence risks, will be greatly reduced where an estimator is more professional in cost plan development. An experienced estimator is therefore critically important to producing high-quality and reliable cost plans. It is not surprising that these top-five risk factors are ranked high in terms of extent of occurrence and impacts. The risk factors are design-related and at the preconstruction phase, and such could be difficult to predict in advance in most large-scale projects, Odeyinka *et al.,* (2010) suggested. However, during the construction phase, as more information is available, designers/clients may suggest changes to the scope of work to ensure their objectives are met. Since the reliability of ECP and OTS depends on available pre-construction information, it is predictable that any change may cause variability between the ECP and OTS.

CONCLUSION AND FURTHER RESEARCH

The current assessment explored the risk factors producing variability between design-stage ECPs and OTS and evaluated the degree of agreement amongst three groups of consultants (Architects, QS and PMs). Findings revealed variation between ECPs and OTS (inflated risks) within the region of +1% and 23.86%. This research establishes and prioritises risk factors contributing to this increase, and this may affect commercial project development budgeting in NZ. Within the confines of the data collected, mean scoring analysis revealed the top five risk variables in traditionally procured commercial projects that influence variability between design-stage ECPs and OTS: scope change (owner's requirements), project complexity, information quality and flow requirements, availability of design information, and consultants' skills. Furthermore, Kendall's concordance analysis found a high level of participants' agreement in their rank-ordering of the relative importance of the factors identified. Results showed that these are preconstruction risk factors which have a high bearing on clients' expenditure. Therefore, studying and ranking of risk factors by extent and impact in projects helps the consultants to plan for appropriate responses to these risks according to the priority of occurrence and the importance of impact.

As a main contribution, this study broadens awareness of researchers in the global construction community regarding the relationship between construction costs and various risk variables, particularly for those countries where this problem is under-researched. Although, the research was conducted to identify the significant risk factors in NZ commercial construction projects, the results can be applied to construction projects implemented in any of developed and developing countries. The sample size used in this study is more favourable than those in earlier studies in the same field. The knowledge also provides proper risk analysis (guidelines) that could assist construction consultants in measuring cost risks and managing practical risk control. Thus, consultants are more able to accurately conduct risk analysis to identify potential threats at an early stage of the project and to maximize the project-budget benefits by creating a cost risk mitigation plan using risk management approach. These could assist NZ stakeholders play a key role in improving the accuracy of cost forecast in the construction market; thus, enabling pro-active management of project owner's expenditure.

Since this study focused on traditionally procured building projects, future research could explore the development of models for assessing risk impacts on the variability between design-stage ECPs and OTS in other procurement methods, such as 'design and build' procured projects, with the aim of comparing the outcome with the present study.

REFERENCES

Adafin, J, Rotimi, J O B and Wilkinson, S (2015) Why do the design-stage elemental cost plan and final tender sum differ in New Zealand? *Journal of Financial Management of Property and Construction*, 20(**2**), 116-131.

Adafin, J, Rotimi, J O B and Wilkinson, S (2016) Risk impact assessments in project budget development: Architects' perspectives, *Architecural Engineering and Design Management*, 12(**3**), 189-204.

Adafin, J K (2017) *Prediction of Final Tender Sums of Construction Projects from the Design-Stage Elemental Cost Plans: A Decision Support Tool for New Zealand*. PhD Thesis, The University of Auckland, Auckland, New Zealand.

Adafin, J, Rotimi, J O B and Wilkinson, S (2018) Risk impact assessments in project budget development: Quantity surveyors' perspectives, *International Journal of Construction Management*, 12(**3**), 1-16.

Agyekum-Mensah, G (2018) The degree of accuracy and factors that influence the uncertainty of SME cost estimates, *International Journal of Construction Management*, 19(**5**), 413-426.

Akintoye, A (2000) Analysis of factors influencing project cost estimating practice, *Construction Management and Economics*, 18(**1**), 77-89.

Akintoye, A S and MacLeod, M J (1997) Risk analysis and management in construction, *International Journal of Project Management*, 15(**1**), 31-38.

Ameyaw, E E, Chan, A P C, Owusu-Manu, D G and Coleman, E (2015) A fuzzy model for evaluating risk impacts on variability between contract sum and final account in government-funded construction projects, *Journal of Facilities Management*, 13(**1**), 45-69.

Arif, F, Lodi, S H and Azhar, N (2015) Factors influencing accuracy of construction project cost estimates in Pakistan: perception and reality, *International Journal Construction Management*, 15(**1**), 59-70.

Carter, B, Hancock, T, Morin, J and Robins, N (1994) *Introducing Riskman Methodology: the European Project Risk Management Methodology*. Oxford: Blackwell Publishing.

Doyle, A and Hughes, W (2000) The influence of project complexity on estimating accuracy. *In: A*kintoye, A (Ed.), *Proceedings 16th Annual ARCOM Conference*, 6-8 September 2000, Glasgow, UK. Association of Researchers in Construction Management, Vol. 2, 623-34.

El-Sayegh, S M and Mansour, M H (2015) Risk assessment and allocation in highway construction projects in the UAE, *ASCE Journal of Management in Engineering*, 31(**6**), 1-11.

Enshassi, A Mohamed, S and Abdel-Hadi, M (2013) Factors affecting the accuracy of pre-tender cost estimates in the Gaza strip, *Construction in Developing Countres*, 18(**1**), 73-94.

Fellows, R and Liu, A (2008) *Research Methods for Construction*. Oxford: Blackwell Publishing Ltd.

Hwang, B G, Zhao, X and Toh, L P (2014) Risk management in small construction projects in Singapore: status, barriers and impact, *International Journal of Project Management*, 32, 116-124.

Jaggar, D, Ross, A, Smith, J and Love, P E D (2002) *Building Design Cost Management*. Oxford: Blackwell Science.

Kassem, M A, Khoiry, M A and Hamzah, N (2019) Risk factors in oil and gas construction projects in developing countries: A case study, *International Journal of Energy Sector Management*, https://doi.org/10.1108/IJESM-11-2018-0002.

Ling, Y Y and Boo, J H S (2001) Improving the accuracy estimates of building of approximate projects, *Building Research and Information*, 29(**4**), 312-318.

Love, P E D and Ahiaga-Dagbui, D D (2018) Debunking fake news in a post-truth era: the plausible untruths of cost underestimation in transport infrastructure projects, *Transport Research Part a*, 113(**2018**), 357-368.

Ministry of Business Innovation and Employment (2014) *Annual Report*. New Zealand: New Zealand Government.

Morrison, N (1984) The accuracy of quantity surveyors' cost estimating, *Construction Management and Economics*, 2(**1**), 57-75.

Moser, C A and Kalton, G (1981) *Survey Methods in Social Investigation*. UK: Heinemann Educational.

Naoum, S G (2007) *Dissertation Research and Writing for Construction Students*. UK: Elsevier Ltd.

Nworgu, B G (2006) *Educational Research: Basic Issues and Methodology*. Nigeria: Wisdom Publishers Ltd.

Odeyinka, H, Larkin, K, Weatherup, R, Cunningham, G, McKane, M and Bogle, G (2012) *Modelling Risk Impacts on the Variability Between Contract Sum and Final Account*. UK: Royal Institution of Chartered Surveyors, 1- 19.

Odeyinka, H A (2010) Assessing risk impacts on the budgetary reliability of design stage elemental cost plan. Available from http://www.docstoc.com/docs/99896893/built_environment [Accessed 11/06/2014).

Odeyinka, H, Weatherup, R, Cunningham, G, McKane, M and Larkin, K (2010) Assessing risk impacts on the variability between tender sum and final account, *In*: *Proceedings of RICS COBRA*. London: RICS.

Odusami, K T and Onukwube, H N (2008) Factors affecting the accuracy of pre-tender cost estimate in Nigeria, *In*: *Proceedings of RICS COBRA*. London: RICS.

Offei-Nyako, K, Tham, L C O, Bediako, M, Adobor, C D and Asamoah, R O (2016) Deviations between contract sums and final accounts: the case of capital projects in Ghana, *Journal of Construction Engineering*, Vol 2016, Article ID 2814126, 1-8.

Oladokun, M G, Oladokun, A A and Odesola, I A (2011) Accuracy of pre-tender cost estimates of consultant quantity surveyors in Nigeria, *Journal of International Real Estate and Construction Studies*, 1(**1**), 39 - 52.

Pricewaterhousecoopers (2011) *Valuing the Role of Construction in the New Zealand* economy. New Zealand: The Construction Strategy Group, 81.

Project Management Institute (2008) *A Guide to the Project Management Body of Knowledge 4th Edition*. Pennsylvania: Project Management Institute.

Skitmore, R M Picken, D (2000) The accuracy of pre-tender building price forecasts: An analysis of USA data, *Australian Institute of Quantity Surveyors Refereed Journal*, 4(**1**), 33-39.

Xia, N, Zhong, R and Wu, C (2017) Assessment of stakeholder-related risks in construction projects: Integrated analysis of risk attributes and stakeholder influences, *ASCE Journal of Construction Engineering and Management,* 143(**8**) 04017030.

Yap, J B H, Abdul-Rahman, H, Wang, C and Skitmore, M (2018) Exploring the underlying factors inducing design changes during building production, *Production Planning and Control*, 29(**7**), 586-601.

MEASURING SOCIAL VALUE IN CONSTRUCTION

Gregg Watts[1], Andrew Dainty[2] and Scott Fernie[3]

[1] *School of the Built Environment, University of Salford, The Crescent, Salford, M5 4WT, UK*

[2&3] *School of Architecture, Building and Civil Engineering, Loughborough University, Ashby Road, Loughborough, Leicestershire, L311 3TU, UK*

Within the UK construction industry Social Value (SV) is a public sector procurement criterion of such importance that how a contractor engages with SV could ultimately be the difference between procurement success and failure. Contactors are increasingly expected to measure and communicate their SV. Therefore, they must do so in a way that is understood by numerous clients simultaneously or must measure and communicate SV numerous different ways for each of the clients they work with. This is due to clients and contractors arguably having unique SV interpretations, and so reaching an agreed definition is often problematic. It can be said that a conflict exists at the heart of SV between the subjective nature of SV and the objective way SV is expected to be measured and communicated. Popular SV measurement tools attempt to circumvent these problems by reducing SV to monetary metrics. Although these arguably miss the wider, nuanced and more difficult to measure aspects of SV. The aim of this paper is to explore how the wider and nuanced aspects not captured in financial metrics can be measured and communicated in a way that is understood by multiple stakeholders simultaneously. After a review of existing SV measurement tools interviews and questionnaires are conducted with construction contractors, public sector clients and the recipients of SV practices. A SV measurement tool is then developed that addresses the subjective nature of SV in an attempt to reconcile the conflict at the heart of the heart of the concept. The research findings reveal the tool measures and communicates the subjective nature of SV in a way that is simultaneously understood by diverse stakeholders.

Keywords: Social Value Act, legitimacy theory, procurement, CSR, measurement.

INTRODUCTION

The construction industry has historically been associated with heavy environmental exploitation and an aggressive attitude towards both clients and society (Barthorpe, 2010). It is argued that construction has more reason than most to adopt and embrace Corporate Social Responsibility (CSR) (Murray and Dainty, 2009). Whilst the industry in places has started to embrace CSR, the focus of effort has increasingly concentrated on environmental aspects over social (Loosemore *et al.,* 2018). Arguably this is largely due to both the ease at which environmental criterion can be measured compared to social criterion and the importance that has been placed upon environmental factors in wider society. However, there is now a growing importance being placed upon measuring and communicating social value in the UK construction industry (Raiden *et al.,* 2019). Despite this increasing importance reaching widely agreed definitions are difficult due to the concepts' subjective and ambiguous nature as SV ultimately comes to mean different things to different people (Watts *et al.,*

[1] g.n.watts@salford.ac.uk

Watts, G, Dainty, A and Fernie, S (2019) Measuring Social Value in Construction *In:* Gorse, C and Neilson, C J (Eds) *Proceedings of the 35th Annual ARCOM Conference,* 2-4 September 2019, Leeds, UK, Association of Researchers in Construction Management, 54-63.

2018). Yet simultaneously there is an objective need for contractors to measure their social value practices and communicate any results in an understandable manner in order to experience the procurement benefits available. To help meet this measurement and communication need there are a wealth of competing social value measurement tools available. However, these are largely reductionist, assigning a monetary figure to the social value created. Whilst this approach has benefits, criticisms include the factors lost when complex SV practices are simplified to monetary metrics, leading to calls for a more qualitative approach (Watson *et al.,* 2016). This paper addresses such calls and develops a SV measurement tool that measures the wider and more nuanced aspects of SV communicating them in a way that can be understood by numerous stakeholders simultaneously. The tool addresses the tensions created by the objective need to measure and communicate the subjective concept of SV offering a workable solution for the industry in measuring SV with non-financial metrics.

Defining CSR and Social Value

CSR is inherently a subjective concept as it means different things to different people (Watts *et al.,* 2018). An advantage to such subjectivity is that each stakeholder can arrive at their own interpretation (Griffith, 2011). However, this has resulted in the lack of a widely agreed definition (Blowfield and Murray, 2011) with growing interest in the concept serving only to increase the variety of definitions proposed (Carroll, 2015). There are arguably two distinct approaches. The first, one of flexibility, allowing stakeholders to embrace whichever unique definition best suits their individual needs (van Marrewijk, 2003). The second considers CSR as a broad concept relevant to wider constituencies, which allows numerous themes and shared interpretations to exist (Barthorpe, 2010). Such approaches have resulted in definitions that complement, overlap and differ from one another, serving to further exaggerate attempts to reach an agreed CSR understanding between different parties (Zhao *et al.,* 2012). Confusions are also perpetuated by the different importance and weighting given to each constituent part of CSR by individual stakeholders. Therefore, the subjective nature of CSR and SV also arguably serve to restrict the development of the concepts and make it increasingly difficult for one party to clearly communicate with another.

Whilst construction contractors have always had an awareness of the social aspects of CSR (Barthorpe, 2010) it was the introduction of the SVA that arguably brought the idea of SV into mainstream business consciousness (Watson *et al.,* 2016). However, as the term SV is subject to the same arguments as CSR with regards to its subjectivity (Loosemore and Higgon, 2016) it has been argued that SV refers to an actionable concept and something that will contribute to both immediate stakeholders and wider society in general (Kuratko *et al.,* 2017; Watson *et al.,* 2016). It is also argued that the emphasis should be placed on how the generated social value extends above and beyond the actual value of the goods and services that are the result of a transaction (Agrawal *et al.,* 2015). However, the specific concept of social value is still in its infancy, with widespread and long-term examples of success stories hard to find (Loosemore, 2016). Nevertheless, examples have been provided from a government review that include a social enterprise hiring homeless people, a local taxi business employing apprentices and a multinational organisation raising money for a charity partner (Cabinet Office, 2014). The review also highlights the barriers that the process of embedding social value in UK business is currently facing, which include a lack of intent from those procuring public sector works and a lack of consistent

understanding and agreement as to what social value actually is (Cabinet Office, 2014). This lack of social value consensus is arguably a downside to the concept's subjective nature in which multiple interpretations are encouraged. However, despite this subjective nature, since the introduction of the SVA, there is a greater focus on and need for SV practices to be clearly measured and communicated to increase chances of construction procurement success.

Procurement in the UK Construction Industry

Procurement in the UK construction industry has traditionally revolved around the triumvirate of time, cost and quality, with the contractor who best fulfils these factors the one most likely to be successful (Wong *et al.,* 2012). However, the addition of CSR factors as procurement criterion is slowly increasing throughout construction procurement and has been argued to stem from the beginning of the twentieth century (Hoejmose and Adrien-Kirby, 2012). It is the public sector which can be credited with driving the increasing focus on CSR and SV, with procurement described as both the ideal vehicle to introduce additional performance metrics (Uttam and Le Lan Roos, 2015) and a perfect mechanism through which public clients can achieve their CSR agendas and policy change (Correia *et al.,* 2013).

The weighting of CSR criterion in procurement is argued to be around 10% (Varnas *et al.,* 2009; Uttam and Le Lan Roos, 2015). Therefore, how effectively a contractor embraces CSR could ultimately be the difference between procurement success or failure (Loosemore, 2016). It is arguably not imperative that SV is measured by contractors, but those who do are in a greater position to be successful in any procurement that includes SV criterion, such as public sector work. Questions may then be asked as to why contractors would choose to work for the public sector if additional requirements are expected, such as the need to measure and communicate SV. Especially as government statistics show that the public sector only accounts for around 26% of the UK construction output, with the private sector contributing around 74% each year (Rhodes, 2015). However, the same government report shows that in times of economic uncertainty where private sector construction workload can reduce significantly, public sector workload can remain fairly buoyant (Rhodes, 2015). The increasing use of social factors has arguably been given more legitimacy in the construction industry by the introduction of the Public Services (Social Value) Act (2012). The Social Value Act (SVA) places a legal duty on public bodies to consider how the procurement choices they make can lead to additional social value, instead of simply awarding projects based on the lowest immediate cost (Loosemore, 2016). Contractors are therefore required to both measure and communicate their social value to public sector clients during procurement (Loosemore and Higgon, 2016) to allow clients to make informed procurement decisions. However, with no widely agreed definition of social value and with multiple stakeholders each holding somewhat unique interpretations, clear measurement and communication is proving to be difficult (Loosemore and Higgon, 2016).

Social value has objective requirements in that it has to be measured, communicated and understood during procurement (Loosemore and Higgon, 2016). This contributes to the tension at the heart of the concept where interpretations don't align. This tension arguably manifests itself in unsuccessful procurement attempts and leads to inconsistent measurement practices and a lack of rigour around how outcomes are quantified and compared (Cabinet Office, 2014). Therefore, to improve chances of

procurement success there is a real need for robust measurement of SV in a way that embraces the subjectivity of the concept whilst meeting the concepts objective needs.

Measuring Social Value

There was a growing need to measure social value before the introduction of the SVA (Blowfield and Murray, 2011). However, the SVA placed a legal duty upon public bodies to assess and compare the social value contractors offered, resulting in an increased contractor focus on the measurement and communication of SV (Watson *et al.,* 2016). For the environmental aspects of CSR, measurements have taken the form of the total reduction in carbon emissions or the total number of trees planted, and basic SV measurement has included practices such as counting the total number of apprentice positions created (Agol *et al.,* 2014; Mirza-Davies, 2016). Where SV measurement approaches have attempted to be more detailed, leading tools such as Social Return on Investment (SROI) have been proposed (Bridgeman *et al.,* 2015). Social Value Portal and Local Multiplier 3 are also popular measurement tools, and despite all reducing SV to a monetary metric, there is still little consistency in the approaches taken and calculations used. It is argued that all measurement tools lack a comparable output (Gjolberg, 2009) largely due to the ambiguity that surrounds CSR and SV concepts (Korhonen, 2003). Therefore, it is arguably of no surprise that a widely agreed method of CSR measurement is yet to be produced (Venturelli *et al.,* 2017). Despite the issues encountered in the measurement of CSR, attempts have still been made to measure SV. However, such attempts have been fraught with similar difficulties again largely due to the subjectivity of the concept and differing interpretations that exist amongst stakeholders (Loosemore, 2016). This has resulted in no single measurement method being widely adopted.

However, those methods that do utilise financial metrics can arguably advertise benefits such as universal understanding of communications and also wide application and comparison capabilities (Watson *et al.,* 2016). A summary of leading SV measurement tools can be seen in table 1. Reductionist and objective methods of assigning monetary amounts to social value have been criticised for expressing complex social issues in simplistic monetary terms, potentially undervaluing the true extent of the benefits realised and leaving calls for a more qualitative tool unanswered (Watson *et al.,* 2016). Criticisms of using quantitative monetary metrics to measure largely qualitative phenomena also include the argument that wider social value does not lend itself to be easily measured and that difficult to measure social and ecological factors can be missed (Korhonen, 2003). Other criticisms include the nuanced positive impacts created by providing things such as a pleasant home life, an improvement of community spirit, and helping people gain secure employment can often be overlooked, and as quantitative monetary outputs can be compared, it can lead people to believe SV practices can be easily interchanged if the same end value is achieved (Korhonen, 2003). The problem therefore exists that by adopting non-financial metrics to measure social value, any social value measurement tool could potentially alienate stakeholders who do not share that interpretation of what social value means. However, as table 1 reveals, the majority of leading SV measurement tools all utilise monetary metrics and the majority of accompanying literature also has the same focus. Therefore, a gap in current research and practice exists of how to measure SV with non-financial metrics that can appease multiple stakeholders who each have a unique and subjective interpretation.

Title	Cost	Description	Advantages	Disadvantages	Comment
GIIRS	$4,000 per annum	A tool designed to assist investors in understanding the impact the organisations they invest in have upon numerous stakeholders	• Analyses an orgs impact on workers, customers, community and the environment • Allows results to be recorded, measured and viewed in graph form • Provides an easy to understand medal/star rating	• Aimed at investors • Assess the impact organisations have generally and is not aimed at measuring individuals • Scores based on perception of fund managers • The scores given to organisations may not be easily understood	A tool designed for investors measuring the impact of the organisations they fund. Assigns a score and not a monetary metric. Not suitable for WD use
Global Reporting Initiative (GRP)	Free and subscription	Helps organisations understand and communicate their impact upon society and the environment by introducing expected reported standards.	• Extensively used • Focusses upon clear communication • Can be used internationally	• Doesn't focus on impact measurement • The metrics are numerous and broad and so can be difficult to compare	Focussed upon how sustainability is communicated and not necessarily measured therefore offers guidance on areas to measure but not on how to measure them
Human Impact and Profit Scorecard (HIP)	Starts from $500 per month	A tool for investors to identify the positive human impacts that arise from investments. Used quantitative measures of performance which are assigned by HIP.	• Results in a graph to compare investments • Analyses individual companies and assigns a score across 5 areas • Offers validation as an independent third party	• Focusses upon organisations and not individuals • The 'score' is a number / percentage which can be hard to understand	Measures across health, wealth, earth, equality and trust. But is focussed on how organisations behave and not how individuals are impacted
IRIS	Free and subscription	A framework of guidance and metrics which allows investors to track social and environmental 'outputs' of their investments as well as the financial returns	• Uses existing standardised metrics • Allows the user to select the metrics used	• Only really measures 'outputs' • All outputs are in different formats	As outputs are measured the tool doesn't consider identifying and measuring the impacts which are required
LM3	£4,000 first year. £2,000 annually thereafter	A tool that helps organisations calculate the financial impact their spending has on local economies and how this spending then circulates within the economy	• Easy to use • Increasingly well known • Easy to express impact	• Reduces impacts to monetary metrics • Doesn't measure the 'deeper' impacts	A good tool for financial measurement of spending but fails to understand the deeper and more nuanced none-financial impacts organisational actions can have on individuals.
ONS Wellbeing Survey	Free for information. No tool to use so will require WD development costs	A Government recognised and backed survey that identifies and measures societal and personal wellbeing across several categories including life satisfaction, happiness and anxiety	• Measure impact upon individuals • Allows long term trends to be identified • Results in easy to read graphs	• Survey is too detailed to deploy and assess regularly No 'tool' to use - information only • Time consuming to complete	Highly relevant. Measures impact of individuals. Produces an easy to read graph. Can be used for WD purposes but requires amendments to make more suitable for widespread use.
Social Impact Assessment (SIA)	Free	A method of identifying and assessing any social concerns (including areas for positive enhancement and reducing negative impacts).	• Used proactively before a project commences • Impacts can be selected to suit project needs	• Only offers guidance on identification and not measurement	A good framework to adopt to identify what areas can be impacted during projects but not suitable to provide detailed measurement assistance of how practices impact individuals.
Social Return on Investment (SROI)	Free and subscription. Cost of training and additional staff time	A framework method of quantifying and measuring environmental and social value. It results in a financial figure of social value created and a ratio of how this compares to every £1 spent.	• Widely recognised • Results in easy to understand metrics and graph • Promotes stakeholder involvement • Takes into account the original investment	• Results are financial • Monetises all impacts - even if they are not easily monetised • Very resource intensive • Can overlook and fail to identify impacts on individuals	A good comprehensive tool. It considers investment and provides an easy to understand ratio and graph. The financial outputs risk ignoring deeper impacts and broad metrics can overlook impacts on individuals.
Social Value Portal (SVP)	Membership level subscriptions	An online tool that allows organisations to measure their added social value. Uses and results in both financial and non-financial data. Assigns KPI's to goals of stakeholder organisations. Aiming to create a nationally used TOM (Theme/Outcome/Measures) framework for SV reporting	• Attempts to identify metrics for individuals • Easy to use and understand • Offers validation as an independent third party	• Similar to IRIS • Confuses inputs, outputs and impacts • Possibly reduces impact by assigning a monetary value	Offers a logical approach to measuring impacts, but confuses impacts so not suitable. Monetary value is easily understood but can be easily manipulated. None-monetary outputs include quotes and case studies which can't be easily compared

Table 1: A comparison of existing social value measurement tools

The comparison of existing measurement tools revealed non-financial metrics were utilised by the ONS wellbeing survey to good effect as the survey uses broader and arguably subjective metrics in an effort to measure numerous social factors (Dolan and Metcalfe, 2012). This research seeks to build upon these findings to develop a non-financial social value measurement tool that can be widely understood and address the limitations of the tools that use financial metrics. Based upon a single main contracting organisation this research seeks to develop and launch a tool aimed at measuring and communicating the social value created by construction industry apprenticeship and work experience programmes. Apprenticeship placements are arguably one of the most prevalent examples of the practices demonstrating the social side of contractor CSR (Morton *et al.,* 2011) with the Government reporting that in 2015/16 the construction industry hired approximately 21,000 apprentices (Mirza-Davies 2016). Therefore, the SV created by such programmes can have a profound

impact upon thousands of individuals both directly and indirectly, with this research seeking to develop a tool to measure and communicate such non-financial impacts.

METHOD

There are three broad stages to the research conducted. The first consists of interviews to help develop the measurement tool, the second involved the distribution of the tool and assessment of its validity and the third stage involves the updating and use of the tool and further interviews with key stakeholders to verify the measurement tool's effectiveness. For the first research stage twenty semi-structured face to face interviews were conducted with staff from a single main contactor to ascertain their views and requirements on a non-financial SV measurement tool. Interviewees were selected using stratified random sampling to ensure participants represented different job roles. Six semi-structured face to face interviews were also conducted with members of procurement teams from public sector bodies with their views and requirements of social value measurement tools discussed. Purposive sampling was utilised to ensure suitable public sector interviewees were selected that best informed the research. An online search was conducted of public sector bodies whose websites state they use the SVA in their construction procurement. Emails were then sent outlining the research and requesting interview participation. This deductive research step was conducted with the intention of eliciting a set of requirements and features that would inform the development of a SV measurement tool.

The results of the interviews were then coded. The codes used were the key requirements of any potential social value measurement tool that emerged from the interviews and literature review. This allowed the responses to be assigned into categories, so the key requirements and potential metrics of a tool could be easily identified. From the results a SV measurement tool was developed in the form of a questionnaire to be distributed to participants for them to rate themselves against several criteria that was judged important from the interviews.

The second research stage involved the piloting of the SV measurement tool to the ten participants of a two-week work experience programme. Nine semi-structured interviews were then conducted, five with participants from the work experience programme, two with the contractor staff in charge of the programme, and two with public sector clients, with the responsibility for the procurement of construction works. The clients were currently working with the contractor on live projects and so interview participants were identified after discussions with the contractor management staff. The interviews focussed around client satisfaction with the output of the SV measurement tool. The results of the interviews revealed both beneficial aspects to the tool and several drawbacks.

The third research stage involved the further development of the SV measurement tool based on the interview feedback. The tool in its revised format was then piloted and distributed to apprentices with semi structured interviews conducted with each of the eight participants on the programme and the single contractor staff member who had responsibility for the programme. Interviews focussed on the perceived success and failures of the SV measurement tool, its accuracy and ease of completion by the participants and the clarity and relevance of the results communicated.

FINDINGS AND DISCUSSION

During several interviews as part of the first research stage it was identified that a SV measurement tool with non-financial metrics was required by both contractors and

clients. It was also confirmed that the same metrics needed to be understood by a broad group of stakeholders. Requirements also included a tool that was easy for the contractor to distribute and use, and simple for participants to complete. As these requirements did not overlap existing measurement tools a new social value measurement tool was developed. The findings of Watts *et al.,* (2018) were built upon in that ambiguous language had been shown to allow the successful communication of social value to multiple stakeholders. Allowing each to understand the contractor's communications but have their own interpretation.

The non-financial ONS wellbeing index metrics were identified as ambiguous but specific enough to meet numerous stakeholders demands simultaneously. In that metrics such as life satisfaction, worthwhile, and happiness were widely understood by all stakeholders, but each had a slightly different interpretation. This could prove beneficial for any SV measurement tool as it could use the same metrics and therefore the results could be widely shared and understood. From the list of stakeholder requirements, a Microsoft Excel based measurement tool was developed as it fit the needs of contractor staff such as using familiar software and being easy to use and share, and also met the needs of public sector bodies in that results could be put into easy to communicate formats. This tool utilised the ONS metrics the interviewee's felt best illustrated the intended impact of social value practices, and also new metrics that were repeatedly raised throughout the interviews such as aspiration, confidence and motivation. The ONS survey has been described as a well-established method of collecting social value data (Dolan and Metcalfe, 2012) and was therefore used as the base and template from which to develop a SV measurement tool. The approach validated in the ONS survey was a questionnaire distributed directly to participants. The ONS survey questionnaire asks participants to rate themselves on a scale of 1-10 against questions asked under each heading. A similar approach was adopted in this research with the social value measurement tool participants asked to rate themselves on a Likert scale of 1-5 regarding their experience, ability and knowledge, with 5 indicating they felt they had the highest experience, ability and knowledge and 1 that their experience, ability and knowledge was basic or lacking. Three questions were asked under each of the six headings and the questionnaire was distributed twice, once at the start of the CSR activity, the other at the end to capture the participants scores for each metric before the SV programme and again after. The results would then be compared and plotted on a graph (figure 1) to illustrate any positive (or negative) changes that may have occurred - evidencing the social value the activity has generated.

The second research stage was the piloting of the measurement tool on a work experience programme and interviewing those involved. The paper-based SV measurement tool questionnaire was developed and distributed to the work experience participants at the start and end of the programme with the same questions in the same format asked on both occasions. The interviews with contractor staff identified several drawbacks to the tool such as the time taken by the contractor staff members to collate and compile all results and the time taken by participants to complete. The interviews with the work experience participants also revealed that by asking the questions twice, at the start and at the end of the CSR activity, most participants were scoring themselves highly on the first set of questions, and so could not improve upon their initial score at the end. At first this was thought to be possibly due to ineffective CSR practices, however, the interviews revealed that participants purposefully ‘overestimated’ their ability by completing a higher score at the start as they wanted to be seen to have knowledge and competence, even if this was not the case. This was

despite being told before the completion of the tool that the results were to monitor the effectiveness of the programme and not the participants' current ability. It was therefore decided that 'before' and 'after' questions should be combined with participants asked to rate both simultaneously at the end of the activity. The interviews also revealed that some found the questions asked took too long to complete and so it was decided to reduce the number of questions asked under each category from three to two. The client interviews were positive with both clients interviewed finding the impact graph (figure 1) easy to read and understand and were happy with the categories measured. It was reported that the impact graph solved issues clients were having over the non-financial measurement of social value and the communicating of value generated from activities in a clear way that they understood.

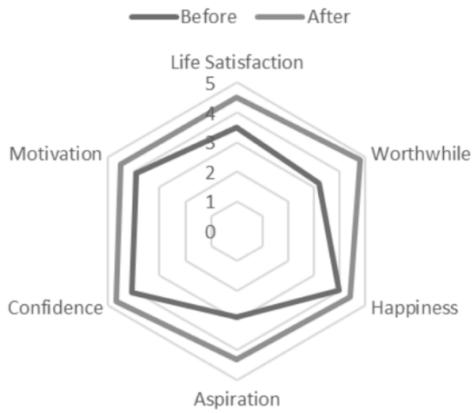


Figure 1: Social Value Impact Graph

The third research stage involved the piloting of the SV measurement tool in its new format with reduced question numbers and both 'before' and 'after' questions asked at the same time at the end of the activity. The contractor interview revealed the SV measurement tool was easy to distribute and collate and allowed the contractor to monitor the apprenticeship programme against the non-financial metrics used to see how improvements could be made and to see the impacts of programme decisions on participant wellbeing. The participant interviews revealed the SV measurement tool was easy and straight forward to complete and asking both 'before' and 'after' questions at the same time allowed them to reflect and complete the questions more accurately. As it was already reported that clients were happy with the presentation and communication of the results the SV measurement tool was therefore deemed a success in that for this contractor and the clients interviewed in the research, the tool allowed the subjective concept of SV to be measured and communicated in an objective way using non-financial metrics.

CONCLUSION

This paper presented the development of a social value measurement tool that addressed the tension and conflict at the heart of social value debates; the subjective nature of the concept and the objective need to measure and communicate social value practices. Such a tension has resulted in the availability of numerous social value measurement tools. However, it was found that no existing tool satisfied both the needs of contractors and several public sector clients simultaneously. The social value measurement tool developed was based upon the ONS wellbeing survey and utilised non-financial metrics in the shape of ambiguous terminology. This allowed clients to

interpret the measurement categories in ways that suited their own needs and allowed the contractor to communicate the results to several clients simultaneously. The tool was sought to address deficiencies identified in other measurement tools and to measure SV in a practical and pragmatic manner. In this scenario, and for the contractor and clients interviewed the tool was deemed a success. The findings of this research will assist the construction industry by providing a method of measuring and communicating non-financial social value that has been accepted and embraced by multiple stakeholders simultaneously in a way previous attempts at social value measurement have not. This research contributes to the understanding of how the subjective needs of social value can be objectively actioned and provides a practical alternative method to measure social value in a non-financial way that meets stakeholder needs.

REFERENCES

Agol, D, Latawiec, A and Strassburg, B (2014) Evaluating impacts of development and conservation projects using sustainability indicators: Opportunities and challenges, *Environmental Impact Assessment Review*, 48, 1-9.

Agrawal, A, Catalini, C and Goldfarb, A (2015) Crowdfunding: Geography, social networks and the timing of investment decisions, *Journal of Economics and Management Strategy*, 24(**2**), 253-274.

Barthorpe, S (2010) Implementing corporate social responsibility in the UK construction industry, *Property Management*, 28(**1**), 4-17.

Blowfield, M and Murray, A (2011) *Corporate Responsibility 2nd Edition*. Oxford: Oxford University Press.

Bridgeman, J, Murdock, A, Maple, P, Townley, C and Graham, J (2015) Putting a value on young people's journey into construction: Introducing SROI at Construction Youth Trust *In:* Raidén, A B and Aboagye-Nimo, E (Eds) *Proceedings of the 31st Annual ARCOM Conference*, 7-9 September 2015, Lincoln, UK, Association of Researchers in Construction Management, 207-216.

Cabinet Office (2015) *Social Value Act Review February 2015*. London: HMSO.

Carroll, A (2015), Corporate Social Responsibility: The centrepiece of competing and complementary frameworks, *Organisational Dynamics*, 44, 87-96.

Correia, F, Howard, M, Hawkins, B, Pye, A and Lamming, R (2013) Low carbon procurement: An emerging agenda, *Journal of Purchasing and Supply Management*, 19(**1**), 58-64.

Dolan, P and, Metcalfe, R (2012) Measuring subjective wellbeing: Recommendations on measures for use by national governments, *Journal of Social Policy*, 41(**2**), 409-427.

Gjolberg, M (2009) Measuring the immeasurable? Constructing an index of CSR practices and CSR performance in 20 countries, *Scandinavian Journal of Management*, 25, 10-22.

Griffith, A (2011) Fulfilling contractors' corporate social responsibilities using standards-based management systems, *International Journal of Construction Management*, 11(**2**), 37-47.

Hoejmose, S and Adrien-Kirby, A (2012) Socially and environmentally responsible procurement: A literature review and future research agenda of managerial issue in the 21st century, *Journal of Purchasing and Supply Management*, 18(**4**), 232-242.

Korhonen, J (2003) Should we measure corporate social responsibility? *Corporate Social Responsibility and Environmental Management*, 10, 25-39.

Kuratko, D, McMullen, J and Hornsby, C (2017) Is your organisation conducive to the continuous creation of social value? Toward a social corporate entrepreneurship scale, *Business Horizons*, 60, 271-283.

Loosemore, M (2016) Social procurement in UK construction projects, *International Journal of Project Management*, 34, 133-144.

Loosemore, M and Higgon, D (2016) *Social Enterprise in the Construction Industry*. Oxford: Routledge/Cabinet Office.

Mirza-Davies, J (2016) *Apprenticeship Statistics: England Briefing Paper Number 06113*, 21 November 2016, House of Commons Library.

Morton, P, Goodwin, A, Kellond, A, Close, K and, Collins, J (2011) investing in the future construction workforce: CSR and work experience placements, *International Journal of Construction Management*, 11(**2**), 49-58.

Murray, M and Dainty, A (Ed.) (2009) *Corporate Social Responsibility in the Construction Industry*. London: Taylor and Francis.

Raidén, A, Loosemore, M, King, A and Gorse, C (2019) *Social Value in Construction*. Abingdon: Routledge.

Uttam, K and Le Lan Roos, C (2015) Competitive dialogue procedure for sustainable public procurement, *Journal of Cleaner Production*, 86, 403-416.

Van Marrewijk, M (2003) concepts and definitions of CSR and corporate sustainability: Between agency and communion, *Journal of Business Ethics*, 44(**2**), 95-105.

Varnas, A, Balfors, B and Faith-Ell, C (2009) Environmental consideration in procurement of construction contracts: Current practice, problems and opportunities in green procurement in the Swedish construction industry, *Journal of Cleaner Production*, 17, 1214-1222.

Venturelli, A, Caputo, F, Leopizzi, R and, Matroleo, F (2017) How can CSR identity be evaluated? A pilot study using a Fuzzy Expert System, *Journal of Cleaner Production,* 141, 1000-1010.

Watson, K J, Evans, J, Karvonen, A and Whitley, T (2016) Capturing the social value of buildings: The promise of Social Return on Investment (SROI), *Building and Environment*, 103, 289-301.

Watts, G, Dainty, A and Fernie, S (2018) Paradox and Legitimacy in construction: How CSR reports restrict CSR practice, *International Journal of Building Pathology and Adaptation*, 37(**2**), 231-246.

Wong, T N, Lee, L H and Sun, Z (2012) CSR and environmental criteria in supplier selection *In: The 13th Asia Pacific Industrial Engineering and Management Systems Conference (APIEMS 2012) and 15th Asia Pacific Regional Meeting of the International Foundation for Production Research*, 2-5 December 2012, Phuket, Thailand, 74-84.

Zhao, Z, Zhao, X, Davidson, K and Zuo, J (2012) A corporate social responsibility indicator system for construction enterprises, *Journal of Cleaner Production*, 29-30, 277-289.

DECOLONISING INDIGENOUS SOCIAL IMPACT RESEARCH USING COMMUNITY-BASED METHODS

George Denny-Smith[1], Martin Loosemore[2], Debbie Barwick[3], Riza Sunindijo[4] and Leanne Piggott[5]

[12&4] *Faculty of the Built Environment, University of New South Wales, Red Centre Building, University Mall, Kensington, NSW, 2033, Australia*

[3] *NSW Indigenous Chamber of Commerce, 5/34 Racecourse Road, Rutherford, NSW, 2320, Australia*

[5] *Centre for Social Impact, University of New South Wales, UNSW Business School, College Rd, Kensington, 2033, Australia*

Indigenous procurement policies encourage the construction sector to provide new training, employment and business opportunities for Indigenous people suffering from economic and social disadvantage. However, the success of these policies is often distorted by the failure of policy evaluations to account for Indigenous perceptions of social value. Since these often differ markedly from non-Indigenous values, this can distort the allocation of funds to Indigenous communities and exacerbate the marginalisation of the communities these policies are meant to help. Drawing on theories of community-based research, this methodological paper seeks to reconceptualise approaches to measuring Indigenous social value in an Indigenous social procurement policy context. Working in partnership with a peak body for Aboriginal business in Australia, we have co-designed a novel approach to Indigenous social impact research that recognises the legitimacy of Indigenous perspectives when investigating the social value Indigenous procurement policies create. We argue that culturally appropriate focus groups (yarning discussion groups) are appropriate in Indigenous social impact research because they prioritise Indigenous people's experiences of Indigenous procurement policies, rather than focusing on simplistic policy targets. As a method that promotes community involvement in social impact research to define how social value is perceived, yarning discussion groups have significant implications for future research seeking to represent Indigeonus perspectives of social value. It is concluded the approach developed here can be operationalised in the field to better understand the nature of Indigenous social value and the impact created by Indigenous procurement policies in Australia and other countries with disadvantaged Indigenous populations.

Keywords: community-based research, Indigenous, social procurement, social value

INTRODUCTION

This methodological paper responds to an urgent need for Indigenous social impact research that is inclusive, relevant and culturally safe and appropriate for Indigenous people and communities (Rogers *et al.,* 2018). In Australia, an Indigenous person is someone who is of Aboriginal or Torres Strait Islander descent who identifies as Aboriginal or Torres Strait Islander and is accepted as such by their community (Department of Aboriginal Affairs 1981). The terms 'Indigenous', 'Aboriginal' and

[1] g.denny-smith@student.unsw.edu.au

Denny-Smith, G, Loosemore, M, Barwick, D, Sunindijo, R and Piggott, L (2019) Decolonising Indigenous Social Impact Research Using Community-Based Methods *In:* Gorse, C and Neilson, C J (Eds) *Proceedings of the 35th Annual ARCOM Conference,* 2-4 September 2019, Leeds, UK, Association of Researchers in Construction Management, 64-73.

'Torres Strait Islander' are capitalised in Australia to reflect their use as proper nouns signifying the political sovereignty of these groups (Maddison 2019). Indigenous Australians are a culturally and geographically diverse population who have had vastly different experiences of colonisation, which has resulted in ongoing systemic disadvantage (DPMC 2019). This is not restricted to Australia; it is repeated in other colonised countries with large Indigenous populations such as Canada, New Zealand and the United States (Maddison 2019).

To address this continuing social inequity, governments in Australia and other countries are turning to social procurement through new Indigenous procurement policies (IPPs) to encourage contractors to deliver social benefits to the Indigenous communities they work in, in the form of work, jobs and training opportunities for Indigenous people and businesses (Australian Government 2015). Social procurement involves the use of existing purchasing practices to create direct and indirect outcomes in disadvantaged communities and IPPs contribute to these outcomes by establishing purchasing and employment targets from Indigenous businesses and people. Purchasers must be aware there are multiple forms of Indigenous businesses (Foley 2013). Some businesses may therefore be excluded from IPPs if practitioners apply strict definitions of what an Indigenous business is. The construction industry is a major contributor to the implementation and outcomes of IPPs because of its possible multiplier effects on other sectors of the economy and the fact it often operates in areas of disadvantage (Loosemore 2016). As the fastest growing industry for Indigenous employment and one of the largest contributors to IPP requirements (ABS 2017), the construction industry is an ideal lens to investigate the social impact IPPs create.

The Australian IPP is categorised under Australia's Indigenous Advancement Strategy that recommends high quality evaluation be integrated into Indigenous policy and be collaborative, timely and culturally inclusive (DPMC 2018). However, recent research has argued that IPP evaluations may not align with Indigenous perceptions of social value, because they rely too heavily on rational contract targets that do not reflect Indigenous perceptions of social value (Denny-Smith and Loosemore 2018). Evaluations are rarely, if ever, built into the design of Indigenous policies or programs, and they are too often undertaken as an afterthought, with insufficient time or resources set aside for quality evaluations, or not evaluated at all (Muir and Dean 2017). Where they do occur, Williams (2018) notes, they are unlikely to reflect Indigenous people's perspectives and experiences because Indigenous people are often not involved in evaluation design, implementation or reporting. Therefore, there is an urgent need to decolonise IPP assessments (Rogers *et al.,* 2018). Decolonised IPP assessments refers to social impact research approaches that are participatory and empowering and prioritise Indigenous perspectives and experiences (ibid.).

In responding to this need, the aim of this paper is to develop a new community-based participatory method for exploring the social value IPPs create in the context of a construction project. By social value we mean the economic, social, cultural, cognitive and health impacts of a construction project on the lives of the people in the community in which it is built (Raiden *et al.,* 2019). Working with a peak body for Aboriginal business in Australia a new decolonised approach to Indigenous social impact research is presented, that utilises a community-based participatory practice to conceptualise a culturally appropriate approach to IPP evaluations. In doing so, we address the present lack of insight on conducting decolonised research that continues to hinder Indigenous research generally (Rogers *et al.,* 2018). Thus, this paper makes

a significant contribution to this area of knowledge, by showing how social impact research can be decolonised to represent the impact IPPs have in Indigenous communities.

Decolonised Research

Indigenous social impact research is a culturally and ethically sensitive area, as research is a "life-changing ceremony" for Indigenous people (Wilson 2008: 61). Unfortunately, for Indigenous people, the term 'research' can be linked to colonial histories that extracted and claimed ownership over Indigenous knowledge, arts, and artefacts (Smith 1999), which could limit people's willingness to participate in an IPP evaluation. To address these historical practices, decolonised research is useful to represent Indigenous knowledge, perspectives and methods that resist current evaluation practices in IPPs (Nakata *et al.,* 2012). Given the lack of practical advice on conducting decolonised research, a community-based participatory approach is useful for engaging Indigenous people and developing social impact research methods that address community priorities (Halseth *et al.,* 2016).

Community-based participatory research

Community-based participatory research (Halseth *et al.,* 2016) is based on several basic principles: involving and consulting Indigenous people as legitimate stakeholders in research; developing shared understandings about the aims of research and methods to be used; and appropriately informing Indigenous people about the aims and objectives of a research project. Community-based participatory approaches are increasingly being accepted as an important process in decolonising research because of its collaborative and empowering nature (Simonds and Christopher 2013). This is important for Indigenous people who have historically been marginalised or excluded from the research process, which has resulted in research being treated sceptically and as another form of foreign colonialization and suppression (Halseth *et al.,* 2016). Thus, community-based participatory ensure Indigenous social impact research responds to Indigenous communities' concerns and minimise the risk of community backlash and non-participation (Nakata 2010).

Conducting Indigenous social impact research with community stakeholders provides several benefits. First, collaborative work like this brings together diverse actors to find common values and goals in Indigenous social impact research (Mandell *et al.,* 2016). Second, working with Indigenous stakeholders to design appropriate social impact research resists relegating Indigenous knowledge to the status of the 'other', which promotes Indigenous perceptions of social value in the research process (Smith 1999). Third, this approach involves Indigenous stakeholders from the outset to understand what is important to them, to provide some control over a social impact study with some investment in the results, and to utilise a flexible and project-specific methodology that responds to the key social value priorities to the community in which a project is being built (Price *et al.,* 2012). Wilson (2008) summarises the benefits of conducting research with Indigenous stakeholders, in that it: helps clarify and define research approaches and methods in Indigenous terms; helps researchers learn more about Indigenous research methods; and builds relationships with the Indigenous community, an important aspect of ethical Indigenous research.

As Simonds and Christopher (2013: 2186) state, community-based participatory practices are an "orientation to research that advances the development of culturally cantered research designs…as well as the integration of Indigenous research methods". From a social value perspective, The Urban Aboriginal Knowledge

Network (2015) indicates that such research should be: grounded in community priorities of what constitutes social value; constructed and co-designed between Indigenous stakeholders and social impact researchers; respectful of Indigenous languages, cultural protocols, values, lifecycles and gender(s); beneficial to Indigenous people and organisations who are active participants in social impact research at the level of their choosing; supportive of principles of utility, self-voicing, access and inter-relationality, ownership, control, access and possession of social impact research outcomes; and respectful of Indigenous people's research approaches and protocols, including the methods used to conduct research like story-telling and yarning (Drawson *et al.,* 2017). Drawing on these principles, the following section shows how community-based participatory research has been conducted to develop a culturally appropriate Indigenous social impact research method.

Research Design

Following the principles of community-based participatory research above, the authors worked with the New South Wales Indigenous Chamber of Commerce (NSWICC) to co-design a method for investigating the social value IPPs create. NSWICC is the peak body for Aboriginal business in New South Wales. NSWICC supports the development of Aboriginal businesses and employment in partnership with the NSW Government (NSWICC and NSW Government 2014). Adopting collaborative yarning (Bessarab and Ng'andu 2010), we have co-designed a new method that guides the conduct of social impact research with Indigenous communities. As such, the research design is also consistent with recommendations that community-based and Indigenous research be collaboratively designed (Muir and Dean 2017). Assuming a relational constructionist ontology, which recognises the cultural, relational and community-based nature of social value (Grandy 2018), it adopts a relational epistemology that draws attention to the role of relationships with people and things in helping to construct and understand how social value is perceived (Thayer-Bacon 2010). This is important in community-based and Indigenous research, where undertaking consultation and collaboration with community members prior to designing research requires authentic relationships that allow the researcher to discuss and understand community issues and promotes familiarity between researchers and communities, which enhances the rigour and outcomes of community research (Halseth *et al.,* 2016).

Founded in social constructionism and recommended for being theoretically rigorous, decolonised social impact research designs can provide an intrinsic perspective on Indigenous social value that can result in positive social change (Phillips 2011). Social constructionism privileges the role of communication in the development of jointly constructed meaning. Social constructionist assumptions, therefore, have been developed to understand Indigeonus social reality is based on the relations and connections humans have with the living and non-living world (Chilisa 2012). Thus, Nakata *et al.,* (2012) recommend that decolonised social impact research design must not be a simple framework and must address complex Indigenous knowledge spaces to understand Indigenous worldviews, colonial experiences, contemporary dilemmas, and future goals. The value of a decolonised Indigenous social impact research design is that it actively subverts colonially derived research approaches, requires researchers to reflexively theorise about how knowledge is generated, and incorporates methods that resist colonisation and prioritise people's lived experiences of Indigenous social procurement (Weston and Imas 2018). This research adopts Weston and Imas' (2018) hybrid-liminal decolonised approach, which is reflexively constructed and where

colonially derived methods are subverted and combined productively with the engagement of local Indigenous people. The result of this is the yarning discussion group method that will be employed in the research.

Co-Designed Research

In co-designing this research with NSWICC, to effectively evaluate the social value created by IPPs within the principles of community-based participatory research, we used collaborative yarning to reached shared understandings about the research methods and processes that will be used in the field. Yarning is an Indigenous cultural form of conversation and in this case, collaborative yarning involves researchers and stakeholders exploring and discussing similar and different ideas and explaining concepts to each other that are relevant to Indigenous social impact research, including how social impact research should be conducted and the methods used to collect data (Bessarab and Ng'andu 2010). As a mode of inquiry, yarning is gaining increasing prominence as a rigorous tool for decolonised research (Leeson *et al.,* 2016). Our initial yarns highlighted NSWICC's concerns with the current state of Indigenous procurement policies, including the sustainability of Indigenous businesses who may become dependent on Indigenous procurement policies for continuing work. Face-to-face workshops then provided a chance to properly develop a researcher/stakeholder relationship that helped clarify the research objectives and methodological approach. The researcher is not Indigenous but having childhood friends who are Aboriginal and Torres Strait Islander people drives their interest in this space. This has taught them that respectful Indigenous research must be guided by Indigenous stakeholders, which was integral to developing the relationship with NSWICC that has respectfully interfaced Indigenous perspectives with western modes of research (Leeson *et al.,* 2016).

In developing and designing the methodology for the project, the issue of IPP evaluation was initially raised with NSWICC, suggesting that existing assessment frameworks can be too restrictive or too general, thus not reflecting the changes that people experience as they interact with Indigeonus procurement policies. In response, it was suggested by NSWICC the project needs to work with community to find out what is important, to them, to be investigated in an IPP evaluation. NSWICC advised the author that focus groups could be a culturally appropriate way to involve community in this process and learn more about what indicators of social value should be measure and the appropriate ways to measure those indicators. As a method that allows participant stakeholders to talk about objects and events, thus constructing their own perspectives using their own categorisations and associations, the focus group method is particularly relevant for investigating Indigenous social value (Stewart and Shamdasani 1999). Focus groups are particularly important in community-based research, where community members can contribute to the design, implementation and reporting of data collection processes (Viswanathan *et al.,* 2004). However, focus groups risk dominant voices restricting others from freely participating in the discussion, and therefore must be adapted to be culturally familiar to promote an open discussion allowing attendees a chance to speak uninterrupted (Schneider and Kayseas 2018).

For the above reasons, it was decided a more culturally appropriate method of conducting focus group discussions was required, called a yarning discussion group. Yarning is a culturally safe Indigenous style of conversation and story-telling that is a valid method for gathering qualitative data (Bessarab and Ng’andu 2010).

Storytelling is also a deeply embedded tradition to Indigenous people around the world, which allows people to explain their past and future, celebrate their achievements, organises and gives meaning to their experiences, and motivates their actions (Nakata 2010). Stories are inseparable from theory because they make up theory and are therefore real and legitimate sources of data and ways of being (Gabriel 2018). Furthermore, when used in community-based participatory research, yarning is effective for embedding Indigenous perspectives and methods in the research process (Drawson *et al.,* 2017). Yarning methods, then, are a culturally respectful alternative for traditional focus group discussions (Wilson 2008). Yarning methods are therefore a novel approach to investigate the nature of Indigenous social value that acknowledges and respects Indigenous cultural practices.

As a method for gathering oral knowledge central to Indigenous cultures, Bessarab and Ng'andu (2010) argue yarning is a valid and rigorous method for conducting research with Indigenous people. Chilisa (2012: 131) links the growing acceptance of yarning as a valid research method to theories of ethnophilosophy, that recognise Indigenous people's experiences are encoded in language, folklore, stories, songs, artefacts, culture, and values, that provide "other ways of data collection, analysis, and interpretation of the worldviews of postcolonial and Indigenous societies". Yarning discussion groups are a hybrid-liminal decolonised method because they incorporate Indigenous cultural practices, protocols and forms of knowledge sharing, while subverting the colonial connotations associated with formal focus group discussions and research generally. Therefore, yarning discussion groups create a more comfortable setting for exploring Indigenous social value than traditional focus groups and is consistent with Indigenous cultural knowledge and protocols.

Yarning Discussion Groups

Implementing the yarning discussion groups will involve appending yarning group sessions to several business seminars and workshops NSWICC will hold in 2019. Obtaining ethics clearance to undertake the yarning groups was a complex process requiring ongoing discussion with a University Human Research Ethics Committee (HREC) (HC180886). For example, HREC preferred the research to be conducted from a critical arms-length distance. However, Weston and Imas (2018) assert that engaging participant stakeholders from a distance inhibits learning of new knowledge and continues to marginalise Indigenous perspectives and knowledges. To overcome this dichotomy, we have allowed provision in yarning discussion groups for 'telling space', a culturally appropriate form of self-identification reflecting Indigenous cultural practices that assist in building the researcher's credibility in the yarns (Williams 2007). At the beginning of each yarn, the researcher will tell space by introducing themselves and explaining their motivation for conducting the research, to build rapport with attendees.

Overall, five yarning discussions will be held in various locations across NSW. The sample size of each yarning group will be five to fifteen participant stakeholders. Smaller groups for yarning discussions are a more practical approach to setting up and managing a group that presents greater opportunity for people to talk, allowing deeper discussion of the complex subject of Indigenous social value (Krueger 1994). In total, the sample size will involve between 25-75 participant stakeholders. A smaller sample size (e.g. c. 25) means a study can achieve more depth and significance while a larger sample size (c. 75) can maximise the importance of the project (Charmaz 2012). Yarning discussions will be semi-structured in a way that allows researcher

and participant stakeholders to converse together in a relaxed manner and explore topics of interest relevant to the study of Indigenous social value (Bessarab and Ng'andu 2010). We draw on recent research on 'cultural counterfactuals', and their influence on Indigenous social value creation (Denny-Smith and Loosemore 2018), for the semi-structured framework of yarning discussion groups.

The research team will use an electronic audio recording device to record the discussions and physical notes will be taken on butcher's paper in view of all attendees, to promote transparency of recorded information. Electronic recordings will be transcribed and de-identified to prevent stakeholders from being identified, unless they indicate specifically it is ok to retain their personal information, as a way of promoting Indigenous ownership of research outcomes (Drawson *et al.,* 2017). The purpose of visible notes is twofold. First, it promotes transparency in data collection, as attendees will witness notes being taken down. Second, it allows co-analysis of the initial data, where the research team can ask summary questions of participant stakeholders to confirm the knowledge that has been shared (ibid.). This will ensure the research team gathers relevant data, improving the accuracy and reliability of the gathered data. Thus, the data will be initially thematically analysed based on emergent themes in the handwritten notes. Emergent themes will be summarised and confirmed with participant stakeholders, supporting a constructionist paradigm and providing a rich and detailed account of data (Braun and Clarke 2006).

Inductive thematic data analysis will be conducted in three stages. First, concept maps (Wheeldon and Faubert 2009) developed during yarning groups will highlight key concepts and themes that arise from the yarns and allow participant stakeholders to better frame their perspectives of what should be included in Indigenous social impact research. Concept maps are suited to Indigenous social impact research because they can inform narratives about aspects of Indigenous social procurement and the impact it has on people's lives and communities (Chilisa 2012). At the conclusion of the yarns, the researcher will summarise concept maps with all participant stakeholders in attendance. This co-analysis ensures the data represents the contributions of stakeholders and that no data had been forgotten. Second, electronic transcripts will be analysed using Flick's (2006) coding strategy to inductively identify emergent themes and relationships that illustrate how Indigenous people perceive and make sense of social value. Third, in keeping with the principles of community-based and decolonised research, analysed transcripts will also be distributed to stakeholders for their assistance in ensuring the analysis represents their contributions and remains relevant to topics important to them.

CONCLUSION

This paper proposed a decolonised approach to evaluating the social impact of Indigenous procurement policies in Australia. Guided by principles of community-based participatory research, we have engaged in a decolonising process with NSWICC to co-design a new approach to Indigenous social impact measurement in Australia. Our yarning discussion group method embeds Indigenous cultural practices and forms of knowledge transmission to effectively understand the nature of Indigenous social value. This new contribution to social impact research recognises the importance of Indigenous perspectives in evaluating Indigenous procurement policies and demonstrates how academia can effectively engage with the people and community's Indigenous procurement policies impact. Moreover, it demonstrates that, to evaluate whether social procurement has its intended effects on disadvantaged

groups, beneficiaries must be involved in evaluation design, operation and reporting. We are currently finalising dates for holding yarning discussion groups and recognise that empirical validation will substantially improve the validity of this method. This research benefits social impact researchers and policy evaluators, who can operationalise our method and conduct Indigenous social impact research. The philosophy behind our method, that embedding cultural practices into social impact research is a valid way of evaluating social procurement initiatives, could be applied to other disadvantaged populations globally to produce research outcomes that accurately reflect how they are impacted by social procurement initiatives.

REFERENCES

ABS (2017) *Construction the Biggest Riser in Aboriginal and Torres Strait Islander Industry Data*. Media release. Canberra: Australian Bureau of Statistics.

Australian Government (2015) *Commonwealth Indigenous Procurement Policy: 1 July 2015*, Canberra: Australian Government.

Bessarab, D and Ng'andu, B (2010) Yarning about yarning as a legitimate method in Indigenous research, *International Journal of Critical Indigenous Studies*, 3(**1**), 37-50.

Braun, V and Clarke, V (2006) Using thematic analysis in psychology, *Qualitative Research in Psychology*, 3(**2**), 77-101.

Charmaz, K (2012) Expert voices *In:* S.E Baker and R Edwards (Eds.) *How Many Qualitative Interviews Are Enough? Expert Voices and Early Career Reflections on Sampling and Cases in Qualitative Research*, National Centre for Research Methods Review Paper Southampton, UK: National Centre for Research Methods, 21-22.

Chilisa, B (2012) *Indigenous Research Methodologies*. Thousand Oaks, CA: Sage.

Denny-Smith, G and Loosemore, M (2018) Cultural counterfactuals: Assessing the impact of Indigenous social procurement in Australia, *In:* C Gorse and C J Neilson (Eds.) *Proceedings of the 34th Annual ARCOM Conference*, 3-5 September 2018 Belfast, UK: Association of Researchers in Construction Management, 435-444.

Department of Aboriginal Affairs (1981) *Report on a Review of the Administration of the Working Definition of Aboriginal and Torres Strait Islanders*, Canberra: Department of Aboriginal Affairs.

DPMC (2018) *Indigenous Advancement Strategy: Evaluation Framework*. Canberra: Department of the Prime Minister and Cabinet.

DPMC (2019) *Closing the Gap Report 2019*. Canberra: Department of the Prime Minister and Cabinet.

Drawson, A S, Toombs, E and Mushquash, C J (2017) Indigenous research methods: A systematic review, *The International Indigenous Policy Journal*, 8(**2**).

Flick, U (2006) *An Introduction to Qualitative Research 3rd Edition*. London: Sage.

Foley, D (2013) Jus Sanguinis: The root contention in determining what is an Australian Aboriginal, *Business Indigenous Law Bulletin*, 8(**8**), 25-29.

Gabriel, Y (2018) Stories and narratives, *In:* C Cassell, A.L Cunliffe and G Grandy (Eds.) *The SAGE Handbook of Qualitative Business and Management Research Methods: Methods and Challenges*. London: Sage, 63-81.

Grandy, G (2018) An introduction to constructionism for qualitative researchers in business and management, *In:* C Cassell, A L Cunliffe and G Grandy (Eds.) *The SAGE Handbook of Qualitative Business and Management Research Methods: History and Traditions*. London: Sage, 173-184.

Halseth, G, Markey, S, Ryser, L and Manson, D *(*2016) *Doing Community-Based Research: Perspectives from the Field.* Montreal: McGill-Queen's University Press.

Krueger, R A (1994) *Focus Groups: A Practical Guide for Applied Research 2nd Edition*. Thousand Oaks: Sage.

Leeson, S, Smith, C and Rynne, J (2016) Yarning and appreciative inquiry: the use of culturally appropriate and respectful research methods when working with Aboriginal and Torres Strait Islander women in Australian prisons, *Methodological Innovation*, 9, 1-17.

Loosemore, M (2016) Social procurement in UK construction projects, *International Journal of Project Management*, 34(**2**), 133-144.

Maddison, S (2019) *The Colonial Fantasy: Why White Australia Can't Solve Black Problems*, Crow's Nest, NSW: Allen and Unwin.

Mandell, M, Keast, R and Chamberlain, D (2016) Collaborative networks and the need for a new management language, *Public Management Review*, 19(3), 326-341.

Muir, S and Dean, A (2017) *Evaluating the Outcomes of Programs for Indigenous Families and Communities CFCA Practice Resource - Feb 2017*. Canberra: Child Family Community Australia.

Nakata, M (2010) The cultural interface of Islander and scientific knowledge, *The Australian Journal of Indigenous Education*, 39(**S1**), 53-57.

Nakata, M, *et al., (*2012) Decolonial goals and pedagogies for Indigenous studies, *Decolonization: Indigeneity, Education and Society*, 1(**1**), 120-140.

NSWICC and NSW Government (2014) *Memorandum of Understanding 2014*. Sydney: NSW Government.

Phillips, R (2011) Postcolonial scholarship in social justice research *In:* L Markauskaite, P Freebody and J Irwin (Eds.) *Methodological Choice and Design: Scholarship, Policy and Practice in Social and Educational Research Methods Series 9*. New York: Springer, 157-166.

Price, M, McCoy, B and Mafi, S (2012) Progressing the dialogue about a framework for Aboriginal evaluations: sharing methods and key learnings, *Evaluation Journal of Australia*, 12(**1**), 32-37.

Raiden A, Loosemore, M, King, A and Gorse, C *(*2019) *Social Value in Construction*. London: Routledge.

Rogers, A, Rogers, A, Radcliffe, D, Babyack, S and Layton, T *(*2018) Demonstrating the value of community development: An inclusive evaluation capacity building approach in a non-profit Aboriginal and Torres Strait Islander organisation, *Evaluation Journal of Australia*, 18(**4**), 234-255.

Schneider, B and Kayseas, B (2018) Indigenous qualitative research, *In:* C Cassell, A.L Cunliffe and G Grandy (Eds.) *The SAGE Handbook of Qualitative Business and Management Research Methods*. London: Sage, 154-172.

Simonds, V W and Christopher, S (2013) Adapting western research methods to Indigenous ways of knowing, *American Journal of Public Health*, 103(**12**), 2185-2192.

Smith, L T (1999) *Decolonizing Methodologies: Research and Indigenous Peoples*. Dunedin: University of Otago Press.

Stewart, D W and Shamdasani, P N (1990) *Focus Groups: Theory and Practice, Applied Social Research Methods Series 9*. Newbury Park, CA: Sage.

Thayer-Bacon, B (2010) A pragmatist and feminist relational (**e**)pistemology, *European Journal of Pragmatism and American Philosophy*, 2(II-1).

Urban Aboriginal Knowledge Network [2015] *Guiding Ethical Principles Ottawa: Urban Aboriginal Knowledge Network*. Available from http://uakn.org/wp-content/uploads/2014/10/Guiding-Ethical-Principles_Final_2015_10_22.pdf [Accessed 8/01/2019].

Viswanathan, M, *Ammerman,* A, Eng, E, Gartlehner, G, Lohr, K N, Griffith, D, Rhodes, S, Samuel-Hodge, C, Maty, S, Lux, L, Webb, L, Sutton, S F, Swinson, T, Jackman, A and Whitner, L *(*2004) *Community-Based Participatory Research: Assessing the Evidence.* Evidence Report/Technology Assessment No 99, AHRQ Publication 04-E022- 2 Rockville, MD: Agency for Healthcare Research and Quality.

Weston, A and Imas, J M (2018) Resisting colonization in business management studies: from postcolonialism to decolonization *In:* C Cassell, A.L Cunliffe and G Grandy (Eds.) *The SAGE Handbook of Qualitative Business and Management Research Methods: History and Traditions.* London: Sage, 119-137.

Wheeldon, J and Faubert, J (2009) Framing experience: concept maps, mind maps and data collection in qualitative research, *International Journal of Qualitative Methods*, 8(**3**), 68-83.

Williams, M (2018) Ngaa-bi-nya Aboriginal and Torres Strait Islander program evaluation framework, *Evaluation Journal of Australasia*, 18(**1**), 6-20.

Williams, S T (2007) *Indigenous Values Informing Curriculum and Pedagogical Praxis*. PhD Thesis, Faculty of Education, Deakin University.

Wilson, S (2008) *Research is Ceremony: Indigenous Research Methods*. Winnipeg: Fernwood.

ESTABLISHING DESCRIPTIONS OF BUILDING WORK IN UK

Harry Hussey[1], Niraj Thurairajah[2], Kanchana Ginige[3] and Jack Goulding[4]

[1,2&3] *Department of Architecture and Built Environment, Northumbria University, Newcastle, Upon Tyne, NE1 8ST, UK*

[4] *School of Architecture and Built Environment, University of Wolverhampton, WV1 1LY, UK*

There is continual need to describe building work. Whether programming, estimating, issuing instructions, writing up a journal or other activity, it is difficult to conceive of project situations where such descriptions are not required. It is therefore surprising to find that there is no standard method of describing the physical effort of construction used in the UK. The descriptions in general use in the UK are derived from SMM/ NRM2 (1922-2013) and from quantity surveyors' methods of working. Despite such descriptions being thought to inform about building work, those nine documents, spanning a century, state that labour and other items are not included, deeming that contractors must allow for them. Coupled with that situation, current tendency toward collaboration between designers and contractors at early stage of design increases the need for a means of communication between the parties which expresses financial consequences of designers' decisions. This paper, via critical literature review and comparison of editions, exposes misunderstandings surrounding the use of SMM/NRM2, looking at why it is criticised for failing to do that which was never intended, how information which it is expected to provide may be given effectively, and how a system of dealing with that additional information can synchronise with the existing. The method of constructing such a system requires that 'work', and the products of that work are defined in a particular manner so that it may be observed and recorded. By document analysis and literature synthesis, the requirements for such definition are examined and suggestions given for further work in the field. It is hoped that development will pave the way for a comprehensive standard method of description of building work that takes all factors of contractors' construction cost into consideration.

Keywords: building work, communication, cost significance, descriptions

INTRODUCTION

A chain of events leads to a need for description of building work; the goal - to supply a product whose quality and price are acceptable to the client. Price is established by listing the 'work' to be done and asking contractors for rates for the items listed. It follows that description of the work should be full and accurate.

Descriptions of work currently supplied to contractors for pricing in the UK stem from the use of SMM/NRM2, and are not 'full' (Lee *et al.,* 2014; RICS, 2013) - hence the part that is supplied is in accord with the rules of those documents and quantity surveyors' methods of taking off and abstracting , but what is not supplied has to be

[1] henry.hussey@northumbria.ac.uk

Hussey, H, Thurairajah, N, Ginige, K and Goulding, J (2019) Establishing Descriptions of Building Work in UK *In:* Gorse, C and Neilson, C J (Eds) *Proceedings of the 35th Annual ARCOM Conference,* 2-4 September 2019, Leeds, UK, Association of Researchers in Construction Management, 74-83.

estimated by the contractor. Additionally, although the contractor may be aware of the sort of information that is not included, there is no way of discovering the quanta applicable to a specific building unless a further 'take off' is carried out by the estimator.

That situation comes about because quantity surveyors were originally 'measurers', working for contractors, measuring and listing the work in their own individual way. (Thompson, 1968). They had constant contact with builders, sites and operatives were in touch with costs and aware of the causes of cost variation. The change to working for client bodies meant losing contact with builders' cost, becoming more conscious of clients' costs, i.e., builders' prices, and less concerned with either description of the work or builders' profitability. Their way of measuring was included in the compilation of the Standard Method of Measurement of Building Works (SMM) (1922), satisfying contractors' complaints of variation in descriptions which estimators had to price, providing an equal basis for tendering, but containing problems which were not then or now immediately apparent. One is that the descriptions to be priced are not of pieces of work but of measures, e.g., brickwork is given as a number of square metres of a certain thickness of walling, rather than as walls - an abstract concept rather than a piece of work. Another is that the contractor is deemed to have included all necessary labour in the rates despite being given little information about intricacy or practicality of the work. That situation has changed over the years; early editions of SMM appeared to recognise intricacy, indicated in items such as 'plumbing angles', (removed from 5th edition onward); later editions tend to measure fewer items, particularly if they are not 'cost significant', (to the client). Skoyles, (1981), opined that 'For any industry it is necessary that the designer should be aware of the financial consequences of his design decisions'.

Problems such as those mentioned above give rise to contractors' complaints that bills of quantities (BQ) do not describe their work adequately. The knowledge gap resides in the fact that descriptions in contract documents based upon SMM/NRM2 intentionally do not describe some elements of cost, particularly labour. There appears to be no relevant previous research upon the content of descriptions. Work study might be thought to provide answers, but it is pitched at micro level on the one hand, and the 'elements' are selected by the observer on the other, neither of which aid this study in its aim of establishing standard descriptions of building work that can be used for many purposes.

The problem to be solved is to provide descriptions which are full and accurate, leading to prices which are full and accurate. It is necessary to find a way for information previously excluded to be given to estimators such that the intricacy and relative difficulty of the work is expressed, preferably whilst blending with the existing method of measurement so that change may take place smoothly. To do that, determining the effect of information content in the method of measurement when describing building work, and understanding the degree of change in such descriptions over time is important.

LITERATURE REVIEW

Information required for construction comes from various sources: designer's drawings and specification, quantity surveyors' taking-off, experience and training of contractor's site staff, and not least, the training of site operatives. Daltry, (1971) recognises two types, 'technical', contained in drawings, specifications, and bills of quantities (BQ), and 'control', defining operations, sequence, duration, resource

availability, outputs, etc. Descriptions of 'work', wherever sourced, stem from the century of use of SMM/NRM2, (1922-2013), so all who are trained to be quantity surveyors, estimators, cost managers, and so on are inculcated with it. Consequently, all descriptions tend to be in SMM terms, particularly omitting items relating to cost that SMM/NRM2 do not measure.

In synthesising cost, estimators have, in effect, to construct a virtual building, making it essential that the fullest possible information be contained in the descriptions priced. Thus, there is an intimate connection; cost should be established by the information contained in descriptions. Less than full information leads to more uncertainty regarding cost. Singh and Banjoko (1990) make the point that contractors are expected to use the best of cost estimating and control methods whilst their revenue is based on a less accurate method.

Descriptions should be so constructed that contractor's costs can be recorded and feedback from site be checked against them. The RICS (1966) agreed with that view of estimators' needs, stating as a fundamental duty of the quantity surveyor that accurate and adequate information must be given to the estimator so that the exact nature of the work may be understood.

Nelson (1969), proposing criteria for an information system, includes:

1. Should have operation and task units corresponding to real pieces of work
2. Ability to be sorted into aggregations of like materials, labour skills or plant
3. Packages provided for all tasks, identifying resources, restraints, workpiece identification, location and definition
4. Provision for reporting task progress, resources used and stock

Bandi *et al.,* (2014) appear to agree with Nelson about information requirements, and list shortcomings of BQ, identified by over 20 authors, summarised as follows;

1. No help in programming or work sequencing.
2. No grouping by similar operations, type of operation or activities.
3. No work locations.
4. No reflection of design/production interaction or buildability.
5. No information to establish working time of labour or plant.

The Cabinet Office (2011) saw current information as inaccurate, insufficient and indefinite, causing additional expenditure of 20 to 25%. The resulting report led to the production of PAS 1192-2 (CIC, 2013), requiring 'collaborative working', identifying the collaborators as designers and contractors, requiring contract documents to be aligned with 'industry standards', assuring that no additional work will be necessitated because the same information 'has always been produced'. That could be helpful if the previously produced information had satisfied the needs of all users. The assurance that the same information will be given leads to the thought that therefore the same lack of necessary information will be involved, and the information will continue to be 'inaccurate, insufficient and indefinite'.

'Collaborative working' and information management has been examined by a number of researchers (Fisher and Li Yin, 1992; Moore and Dainty, 2001; Anumba *et al.,* 2008; Demian and Walters, 2014; Collinge and Connaughton, 2017), some finding that scant attention appears to have been given to the quality of the information, and that integrated project culture had not developed from the exercise.

For descriptions stemming from SMM/NRM2; the RICS (1966) rule that surveyors can word descriptions in any way they wish provided the required information is included, hence the documents are responsible for the content, not the wording of descriptions. However, over the past 60 years descriptions have tended to become standardised (Fletcher and Moore, 1965; Monk and Dunstone, 1965; Conseil International du Bâtiment (CIB), 1993; RIBA Enterprises, updated monthly). The Q.S Committee of the RICS (Ferry and Holes, 1967), recommended a form of analysis to make for accurate estimating and costing and better use of data produced by quantity surveyors. Lee *et al.,* (2014) warn against "fitting an item to a standard description rather than ensuring that the description fits the item". It would be beneficial if the current information system were of maximum use to both client and contractor, but whilst the industry does not recognise that it is the system itself which is fragmented, there will be no pressure for improvement. The pity is that when quantity surveyors produce abstracts, information is discarded which contractors could use at a later stage.

The UK is not alone in using descriptions stemming from SMM/NRM. Because of its long standing, SMM has been used as an exemplar for countries around the world. It is in use in Australia,(Rosli *et al.,* 2006), the Caribbean, (Rosli *et al.,* 2006), China, (Yuan and Shen, 2006; Utterback, 2017), India, (Bureau of Indian Standards, 1987), Malaysia, (Bandi *et al.,* 2014), Pakistan, (Rosli *et al.,* 2006), South Africa and other African countries, (Africa Association of Quantity Surveyors, 2015; Siglé *et al.,* 2015) and New Zealand, (Rosli *et al.,* 2006). The USA and Canada use a similar method, based, as are SMM/NRM2, on the premise that information regarding work involved in an item is defined by describing measures of the product of that work, not by consideration of the labour involved. (Project Management Institute, 2006-11).

RESEARCH METHOD

The research method is qualitative in that it consists of two examinations scrutinising in depth the documents germane to the issue in order to determine the effect of information content in the method of measurement when describing building work, and to understand the degree of change in such descriptions over time. The first was to search all editions of SMM/NRM2, looking to see the effect of changes and quantity surveyors' methods of working.

In the second examination, a comparison has been made between similar sections of the earliest and latest editions, i.e. SMM1 Bricklayer section with NRM2 Masonry to establish some of the differences between them (Table 1). The effect is measured subjectively using a Likert scale of 1 to 5, where 1 represents no effect on the information supplied in descriptions, 2 is a small loss of information, 3 a significant loss, 4 a considerable loss and 5 complete loss. Figure 1 shows these results as a histogram. The information needs of operatives on site highlighted by Nelson's (1969) criteria, and the work of Bandi *et al.,* (2014) were used as a basis for examining the differences.

Results of Examinations

The results of the two examinations carried out on the documents are as follows:

The most apparent items of the first examination and implied consequences were:

6. Measuring walls, etc., on centre lines. This treats all walls as if they are straight or curved, so does not allow for intricacy of angles and junctions. That

might be satisfied by separate measurement of each, but there are no such items in any edition.

7. Measuring work in with general items when it must be carried out separately (e.g. beam filling; pointing exposed edges of DPC), thus aggregating differing pieces of work, i.e. pieces of work where one or more depends upon completion of another.
8. Measurement of items as 'extra over'. This is convenient for measurement but can make for more calculation by the estimator.
9. Deeming work to be included when it, and its timing, cannot be calculated from the information provided. This passes the requirement for collecting data, together with its attendant cost, to the contractor.
10. Measuring deductions is not measuring 'works', nor is it necessarily measuring a lack of work, it merely measures lack of materials. Measuring areas around openings would allow for identification of any cost differences.
11. Measuring and describing net area omits information about overall size or shape.
12. Arbitrary divisions hide the possibility of actual cost difference, e.g. 'Thickness and width or girth n.e.300mm stated'; 'Thickness and width or girth over 300mm but n.e.600mm stated'; 'Thickness and width or girth thereafter in 300mm stages'. Actual sizes would be more useful.
13. Excavation given in stages of 2 m. presumably to reflect the extra effort and difficulty involved. A 'standard method' should treat all work in a similar way.
14. Aggregation of items which are not precisely similar.

The second examination compares SMM1 Bricklayer section with NRM2 Masonry. The resulting table is too long to show here, but Table 1 below gives the first 8 SMM1 Bricklayer items with assessment of the effects. A histogram of the effects is shown in Figure 1.

It can be seen that the greatest effect has been in the complete loss of 62 of the 124 items in the one area of Masonry, (column 5) whereas only 8 have been retained from the original edition (column 1)

The results show that the main ways in which NRM2 has reduced the number of items covered is (a) giving individual architects and quantity surveyors the responsibility for providing information in drawings and descriptions by making them mandatory, thus tending to reduce the ‘standard’ aspect, (b) allowing many more items to be ‘spot’ items (because of the number of things not mentioned), again reducing the standardisation of description, and (c) by deeming more information to be included, which means that responsibility for its provision has been removed from the client and added to contractor’s risk.

It seems that those changes run counter to the needs of estimators as expressed in RICS (1966). Such changes may have occurred because clients feel the cost of providing information to estimators is too high, some of the information seems to be unnecessary, and much information seems not to be used.

DISCUSSION

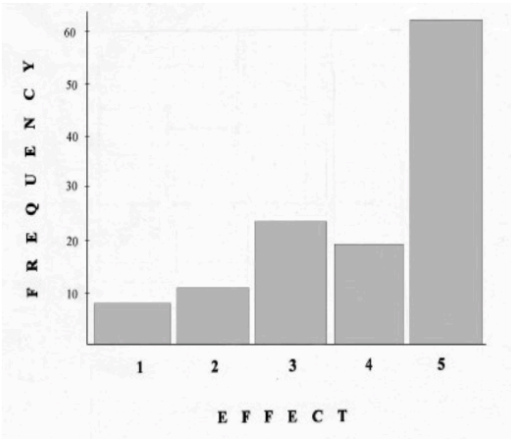
SMM/NRM2 never describe work. They lay down rules for what should be included in descriptions of ‘works'. ‘Work’ and ‘works’ appearing as singular and plural indicate a noun, as does the regular use of ‘the’, (adjective, definite article). The word

therefore cannot be describing the physical effort of the verb 'to work', it refers to output - 'a (piece of) work', 'the works'. In addition, every edition of SMM/NRM2 indicates that it does not, and is not intended to, describe 'work' i.e., the physical labour of construction.

Table 1 Comparison of similar items in SMM1 and NRM2

SMM 1	NRM 2	Effect
(29) Desc bks and mortar also the bond.	Mandatory info. 1, 3, 4,	1
Bkk in rods sup of 272 feet red to 1 ½ B or in yds sup red to 1 B, or if ex 3 ½ B may be yds cu.	Unit, m², thickness stated	1
Bkk in retaining walls shall be sep. given	Not mentioned	5
½ B walls in ft or yds. sup, and 1 B walls if faced or fair b.s.	Unit, m², thickness stated	1
(30) Footings reqd under London Bldg Act or Bye Laws of Local Authority, msd in acc herewith and inc w. gen bkk	Not mentioned	5
(31) All ddts msd net sizes of opgs and recesses, inc. ex width of int reveals, no ddt made for ends of lintels, steps and sills	3.3.2.(1)(a) Deemed inc. note 5. Items 1,2,3, note 6	3
No ddts for strings, sills, lintels and the like n.e. 3" thick	Ditto	3
Ddts for stonework terra cotta work and concrete lintels above 3" in height	Ditto	3
(32) Bkk in backing to masonry given separately and so desc.inc all cutting and waste for bonding	Items 1,2,3, Level 2 - 4, note 1	4
(33) Bkk in underpinning shall be given sep. and so desc.	Not mentioned	5
Wedge up underpinning, ft. sup. and desc.	Not mentioned	5
(34) Rough cutting in ft. sup inc. waste.	Deemed inc. 1.	5
Cutting various types of bkk given sep.	Deemed inc. 1.	5
(35) Bed plates and sleepers on top of walls in ft. run unless msd with bkk. If > 4 ½" on bed, width stated.	Not mentioned	5
(36) Bkk raising old walls or on girders given sep and ht commencing stated.	Not mentioned	5
Prep. tops of old walls for raising in ft. sup.	Not mentioned	5

Figure 1 Effects of changes in descriptions



With the word having both a noun and a verb meaning, some users of the document may be dissatisfied - they expect it to be useful for work scheduling, programming, and other issues which depend upon labour time and output, believing it to describe 'work' in the verb sense.

The fact that it does not takes nothing from its usefulness in establishing total material requirements, but other of its characteristics deny its direct use on site, e.g. arbitrary aggregation of all sizes of concrete columns above or below a stated sectional area, means site management have to re-calculate the quantity of concrete required for each

cross-section and height for ordering purposes. Similarly, aggregating brick walls of the same material and thickness is no help in allocating the next piece of work, or for ensuring materials are stacked in useful positions.

Production of an artefact may require several items under the existing system, e.g., there may be an item of 'brick walls', others of 'Extra over walls for opening perimeter at jambs', 'Forming cavity', 'attached projections', etc. Items of similar description are aggregated, so that the result is not even a part of an artefact, it can represent several parts of many artefacts, such that the description of an individual piece of work is obliterated.

Descriptions of items produced by current methods are not wrong, they do what they intend - provide common ground for tenderers. Unfortunately, over the past century, the myth has been established that what is supplied is adequate; i.e. contractors should know and allow for everything not described, simultaneously bearing the cost of collecting information but not having the opportunity to reflect that cost in the tender.

In addition to problems of description, there is usage of the word 'cost' to consider. Costs, as far as clients are concerned, are dealt with by quantity surveyors rather than designers, (despite designers being responsible for creating cost), so it is likely that the collaborative effort described in PAS1192-2 is expected to be between clients' quantity surveyors and contractors' surveyors. Quantity surveyors work in terms of client's costs, i.e. contractors' prices set against SMM/NRM2 descriptions, (which exclude descriptions of some items of contractors' cost). If collaboration is to be successful and equitable, it would be more appropriate to be dealing with contractors' costs, not their prices.

The requirement on site is a system of describing what is needed of the operatives, given the physical restraints of the work itself, its starting and stopping points, the limits imposed by specification (e.g., work shall not rise by more than X in any one lift), restraints imposed by Health and Safety Acts upon weights lifted, length of working day, and so on. These are calculable when feedback of such information is available from sites, but in order to obtain that feedback, work descriptions must be in the same terms.

That seems a monumental task, but on every site such duties are carried out daily. They are informal, however, with no standardised method, leading to a lack of records, loss of inbuilt knowledge, failure to learn by past mistakes, re-work and consequent costs. The solution does not lie in further revision to SMM/NRM2, or in legislative measures such as PAS1192-2; to establish a method for universal use, the information is already possessed by the industry informally, but there is no industry-wide attempt (if any) to organise it rationally; if it were to do so, companies could become more efficient, less wasteful, more profitable.

A stumbling block is that contractors expect work to be described, but somebody else should deal with it. The existing system will not be replaced by clients' advisors because it suits the clients' purposes; describing work might be at their cost with no obvious reward. Equally, contractors would find it difficult to co-operate in producing something of overall benefit, but which required close observation of their working practices. A system so produced could be regarded by clients' professional advisors as contravening anti-collusion laws. Because of that, it might need to be instituted by Government, as the major client of the industry.

If clients feel, as suggested earlier, that the cost of providing information to contractors is too high, it might be pointed out to them that they do not know the cost of not providing information - could some costly mishaps of recent years have been due to lack of or incorrect information?

CONCLUSIONS

Current methods do what they say they intend - measure building 'works' - but do not attempt to, and are not capable of, describing building work. For contractors to establish their costs with precision, a method of description is needed which supplements the measurement method with full information about work pieces to be executed, enabling the labour, plant and equipment to be identified, allocated, managed and recorded. It is envisaged that the system will be considerably more detailed than SMM/NRM2, with no items of 'extra over'; nothing that is 'deemed to be included'; capable of being aggregated into SMM-type units or architectural elements as necessary.

The proposed system would incorporate all changes indicated above, plus others found necessary during study, satisfy the information needs of operatives on site, conform to Nelson's (1969) criteria, and deal with the complaints of the numerous authors linked in the work of Bandi *et al.,* (2014). Use of such a system could lead rapidly to the construction of a database of builders' costs connected to a library of descriptions of realistic pieces of work whilst being able to be aggregated to find more accurate averages for use with the Standard Method of Measurement, and perhaps to discover more practical groupings of items.

Benefits could be in avoiding re-work; not repeating that which has been carried out by quantity surveyors; making design costs more apparent, leading to less materials wastage; contractors could find it easier to value variations and be paid for them at the end of the month in which they are carried out, making for improved cash flow. Additionally, it would be possible for all stakeholders to use the system, aggregating whichever parts of it are necessary for their purposes - architects' elements for some needs, into 'similar materials' units for others, into production-based units for use on site. Ongoing work is establishing criteria for such a method of description.

The contribution to knowledge will be in extending the information given to contractors so that they are not only pricing on an equal basis, but with the addition of rational and complete information so that tenders can reflect actual cost.

REFERENCES

Africa Association of Quantity Surveyors (2015) *Standard Method of Measuring Building Work for Africa*. Johannesburg: Africa Association of Quantity Surveyors.

Anumba, C J, Pan, J, Issa, R R A and Mutis, I (2008) Collaborative project information management in a semantic web environment Engineering, *Construction and Architectural Management*, 15(**1**), 1-17.

Bandi, S., Abdullah, F. and Amiruddin, R., 2014. Recapitulating the issues Concerning the Applications of the Bills of Quantities. *International Journal of Built Environment and Sustainability*, 1(**1**).

Bureau of Indian Standards (1987) *SP27: Handbook of Method of Measurement of Buildings Works*. New Delhi: Bureau of Indian Standards.

Cabinet Office (2011) *Construction Strategy*. London: Cabinet Office.

Chartered Surveyors' Institution (CSI), National Federation of Building Trades Employers (NFBTE) and the Institute of Builders (IOB) (1935) *Standard Method of Measurement of Building Works (SMM), 3rd Edition*. London: CSI and NFBTE.

Conseil International du Bâtiment (1993) *CIB Master List of Properties for the Arrangement and Presentation of Information in Technical Documents for Design and Construction.* Rotterdam, Netherlands: CIB.

Construction Industry Council (2013) *PAS1192-2:2013 Specification for Information Management for the Capital/Delivery Phase of Construction Projects Using Building Information Modelling*. London: British Standards Institution.

Collinge, W H and Connaughton, J (2017) Mobilizing BIM in a Collaborative Project Environment *In:* K Walsh, R Sacks and I Brilakis (Eds.) *LC3 2017 Volume II - Proceedings of the 25th Annual Conference of the International Group for Lean Construction (IGLC)*, Heraklion, Greece, 251-258.

Daltry, C D (1971) *Information Requirements for Site Operations*. Ascot; IOB.

Demian, P and Walters, D (2014) The advantages of information management through BIM, *Construction Management and Economics*, 32(12), 1153-1165.

Ferry, D J O and Holes, L G (1967) *Rationalisation of Measurement*. London: Royal Institution of Chartered Surveyors.

Fisher, N and Li Yin, S (1992) *Information Management in a Contractor: A Model of the Flow of Project Data*. London: Thomas Telford.

Fletcher, L and Moore, T (1965) *Standard Phraseology for Bills of Quantities*. London: George Goodwin.

Lee, S, Trench, W and Willis, A (2014) *Willis's Elements of Quantity Surveying 12th Edition*. Chichester: John Wiley and Sons, Ltd.

Monk, K W and Dunstone, P H (1965) *Standard Library of Descriptions of Building Works*. London: Estates Gazette Ltd.

Moore, D R and Dainty, A R J (2001) Intra-team boundaries as inhibitors of performance improvement in UK design and build projects: A call for change, *Construction Management and Economics*, 19(**06**), 559-562.

Nelson, J I'a (1969) *Instructions to Operatives CP 10/69*. Watford, UK: Building Research Station.

Rosli, A R, Muzani, M and Siti, N A W (2006) Bills of Quantities - Are they still useful and relevant today? *In*: *International Conference on Construction Industry*, 25th June. Padang, Indonesia.

Project Management Institute (2006, re-affirmed 2011) *Practice Standard for Work Breakdown Structures, Second Edition*. Pennsylvania USA: Project Management Institute, Inc.

Royal Institution of Chartered Surveyors (RICS) and National Federation of Building Trades Employers (NFBTE) (1948) *SMM, 4th Edition*. London: RICS and NFBTE.

RICS and NFBTE (1966) *Comments and Clarifications on SMM*. London: RICS and NFBTE.

RICS and NFBTE (1968) *SMM, 5th Edition (Metric), Incorporating Fitted Carpeting, 1970*. London: RICS and NFBTE.

RICS and NFBTE (1979) *SMM, 6th Edition*. London: RICS and NFBTE.

RICS and Building Employers Confederation (BEC) (1988) *SMM 7th Edition*. London: RICS and BEC.

RICS (2013) *NRM2 - RICS New Rules of Measurement: Detailed Measurement for Building Works*. Coventry: RICS.

Singh, G and Banjoko, O O (1990) The development of a rational bill of quantities, *Construction Management and Economics*, 8(**1**), 31-47.

Skoyles, E R (1981) *Production Orientated Tendering: A Résumé and Re-Examination for the Early Eighties of the Issues Involved*. London: RICS.

Surveyors Institution (SI), the Quantity Surveyors Association (QSA), the National Federation of Building Trades Employers of Great Britain and Ireland (NFBTE) and the Institute of Builders (IOB) (1922) *Standard Method of Measurement of Building Works*, London: SI, QSA, NFBTE and IOB.

SI, QSA, NFBTE and IOB (1927) *Standard Method of Measurement of Building Works 2nd Edition*, London: SI and NFBTE.

Thompson, F M L (1968) *Chartered Surveyors, the Growth of a Profession*. London: Routledge and Kegan Paul Ltd.

Utterback, M (2017) *Construction and Projects in China: Overview*. Available from https://uk.practicallaw.thomsonreuters.com [Accessed 10/12/2017].

World Economic Forum (2016) *Shaping the Future of Construction: A Breakthrough in Mindset and Technology*. Geneva: World Economic Forum.

Yuan, F and Shen, J (2006) *Scope of Construction Contract in Chinese Bill of Quantities Evaluating Mode*. Hong Kong: Chinese Research Institute of Construction Management.

IMPROVING RENOVATION WASTE MANAGEMENT IN SWEDEN: THE ROLE OF THE DEMOLITION COMPANY

Rickard Andersson[1], Martine Buser[2] and Petra Bosch[3]

[1&2] *Division of Construction Management, Department of Architecture and Civil Engineering, Chalmers University of Technology, SE-412 96 Gothenburg, Sweden*

[3] *Technology Management and Economics, Service Management and Logistics, Chalmers, Vera Sandbergs Allé 8, Gothenburg, 412 96, Sweden*

Recent directives expressed by the European commission are targeting that 70 percent of non-hazardous construction and demolition waste should be recycled compared to the current ratio of 50 percent. The common assumption is that these goals are achievable by putting pressure on the construction industry. It is however unclear how these figures can be achieved. Even though there's been a strong focus on waste management activities within the construction management literature, especially during the design and construction phases, the actual work performed by subcontractors is often missing. In particular, the role of the demolition company that is in charge of both the handling of waste on site and its distribution afterwards is overlooked. This paper aims at identifying and analysing the perceived challenges met by these companies to increase recycling. To do so, we build on institutional work which enables us to identify taken for granted institutionalized behaviour on a micro level. Drawing on qualitative research methods, we collect empirical material through semi-structured interviews with both site managers and demolition sub-contractors and observation of practices on site of renovation projects in the region of Gothenburg, Sweden. The result identifies how current institutions are maintained and reproduced, preventing the development of new practices and which actors may disrupt the existing institutions and thus enable change towards more sustainable waste management practices.

Keywords: barriers, waste, demolition, institutional work, sustainable agenda

INTRODUCTION

The focus on sustainable goals and the development of circular economy concepts have put the construction sector under pressure to reduce its consumption of material and energy. Whereas the construction processes have improved, the sector is still a major contributor to the large amount of waste generated annually within the European union being responsible for 25-30% of the total amount of waste. In an attempt to decrease these figures, the European commission is maintaining its pressure by issuing again directives aiming at increasing the amount of non-hazardous waste recycled to 70% (European Commission, 2016). Accordingly, the sector needs to improve and align its practices towards the new targets; waste should either be

[1] rickande@chalmers.se

Andersson, R, Buser, M and Bosch, P (2019) Improving Renovation Waste Management in Sweden: The Role of the Demolition Company *In:* Gorse, C and Neilson, C J (Eds) *Proceedings of the 35th Annual ARCOM Conference,* 2-4 September 2019, Leeds, UK, Association of Researchers in Construction Management, 84-93.

avoided or reduced by optimization of material and processes and start to produce benefits for construction industries.

However, even though a large academic production illustrates the potential of Construction and Demolition Waste (CDW) by providing simulations, life cycle analysis, and mathematical models, and holds with the new directives most of the construction companies are not yet achieving the expected level of reuse or recycle. In particular, the potential of Renovation and Demolition Waste (RDW) is far from been realized (Jin *et al.,* 2019). Studies have identified a number of barriers to explain this situation, beside the low quality of CDW material: Lack of interest and demand from clients; negative attitudes towards reuse practices; lack of training (Park and Tucker, 2017), contract forms, lack of space and information on site (Sezer, 2015), or different valuation practices (Bosch-Sijtsema and Buser, 2017). To overcome these barriers, the majority of the papers insist on ensuring that the construction actors comply with the guidelines and implement the strategies to recycle waste construction materials (Wu *et al.,* 2017), or that these policies and guidelines should be optimized and reinforced (Bosch-Sijtsema and Buser, 2017, Ajayi *et al.,* 2017, Wu *et al.,* 2017).

However, the scholars within sustainable transitions have shown that governmental, national and local legislations and incentives are not enough to ensure the application of new directives but require a transformation of the existing and often taken for granted established way of working (Grin *et al.,* 2010). So, to look at how the established way of working in RDW management (RDWM) can be transformed in order to adopt more sustainable practices, we build on the concept of institutional work. This enables us to get insights into micro-dynamics of institutionalization to discuss some of the challenges of renovation waste management and inform on the lack of generalised processes. In this paper we focus on the demolition companies and their role RDWM process. We are interested in identifying in their discourse which aspects are mobilized to account for the stability of the actual practices and may constitute barriers to the implementation of changes; which aspects are indicating a possible transformation or creation of new practices; and which ones may constitute as disruption of the actual practices.

Whereas the contractor role is often seen as central in this discussion (Alzahrani and Emsley, 2013), we choose to move our focus to the demolition companies and the role they play in RDWM. These companies though often in charge of the deconstruction and demolition of waste on site are often disregarded in the discussion (Bosch-Sijtsema and Buser, 2017). However, their role become central, especially in a Swedish context, as they are not only organising and executing the work on site but commonly decide on what happens to the material afterwards.

Our premise for this paper is that there is an institution of RDWM in which a common understanding is shared of what the formal and unformal processes are as well as norms of conduct, contractual agreement and taken for granted behaviour and shape and are shaped by actor's behaviour (Hampel *et al.,* 2017).

After a presentation of the theoretical frame and the method, we present the outcome from the empirical material and a concluding analysis. The paper contributes to a better understanding to the barriers to improve RDW management practices but also identifies the possibility to change these practices for the construction sector to contribute substantially to the achievement of a sustainable agenda.

Theoretical Frame

To study the lack of efficient RDW Management under the new legislation frame, we adopt the lenses of institutional work as it enables us to study how actors rather "than accepting institutions as innately enduring and their effects as immutable, and to explore the practices and processes associated with actors' endeavours to build up, tear down, elaborate, and contain institutions, as well as amplify or suppress their effects" (Hampel *et al.,* 2017, p.3). Here we define institutions according to Suddaby and Greenwood (2009, p. 176): 'an institution may take the form of juridical regulations, informal rules or codified social arrangements, norms of conduct, or cognitive structures that provide understanding and give meaning to social arrangements'. According to (Greenwood *et al.,* 2008, p.4-5) institutions can be described as 'more or less taken-for granted repetitive social behaviour that is underpinned by normative systems and cognitive understandings that give meaning to social exchange and thus enable self-reproducing social order'. Institutions are socially constructed and maintained by human behaviour, thoughts and feelings and repeated both intentional and unintentionally. The actors of which institutions are built upon are portrayed to be regulated by the institutional structures they are a part of. At the same time capable to gather the necessary resources and awareness to perform work that affects the institutional arrangements (Hampel *et al.,* 2017).

In its original definition, institutional work is defined as "the purposive action of individuals and organizations aimed at creating, maintaining and disrupting institutions" (Lawrence and Suddaby, 2006, p.215) and highlights the how, why and when of this action taking place (Lawrence *et al.,* 2011). Individuals are described as capable beings that both intentionally or unintentionally influence their institutional setting through their behaviour, thoughts and feelings and puts focus on the actor's role in the tension between continuity and change in institutional work (Hampel *et al.,* 2017). These actions may be very dramatic and highly visible or just mundane and hardly noticeable events that are integrated in the daily routines of actors (Lawrence *et al.,* 2009). It illustrates actors as capable to resist changes and that it isn't enough to introduce new innovations or practices, but that it is also necessary to affect the opinions and habits of the ones who are part of the institutional setting (Patterson and Beunen, 2019). Though the focus of institutional work is practice, it has also been influenced by the 'linguistic turn', discourse and narratives are also adopted to study this process (Zilber, 2009). Scholars have shown that actors employ discourse and narratives in different ways to pursue what they call symbolic institutional work (Hampel *et al.,* 2017). These discourses can be mobilised to explicate situations, justify actors and defend course of actions by a selection, combination and editing of events or arguments (Zilber, 2009).

Whereas institutional work has been largely mobilised in many fields the last 20 years, it has made a late entrance in Construction management (Bresnen, 2017, Chan, 2018). Institutional work in construction management literature has focused among others on environmental expertise (Gluch and Bosch-Sijtsema, 2016), design-build management (Urup, 2016), public facility management (Gluch and Svensson, 2018) and inter-organizational projects (Lieftink *et al.,* 2019).

METHOD

The paper presents the preliminary results of an ongoing PhD (2018 -2023) which aim is to document and analyse the management, organisation and practices of RDW in construction and whereas these related practices are converging or not with new

public regulations and sustainable goals. Building on an interpretative approach, it draws on material collected in an ongoing project (2017-2019, Buser and Bosch-Sijtsema, 2018) and the mentioned PhD. The project adopts the lenses of institutional theory, in particular institutional work, to discuss the empirical material.

A starting point to identify the actual practices is to observe how RDW work is performed, therefore participant observation will be mobilized as a main method further in the project. But for the present paper we built on three renovation site visits; two to the same site with six months interval and interviews of the main actors engaged in construction renovation. In addition, we also attended a three-hour workshop organized by a professional association on the topic of circular economy and waste in the construction sector, gathering 22 practitioners. The site visits, which took around two hours were documented with notes and pictures and some discussions were also recorded. The list of 23 interviewees, presented in table 1, consists of actors engaged in renovation waste management. We have gathered their experiences and opinions regarding the actual practices of handling waste management from the perspective of the demolition companies. We have carried out 18 interviews including six demolition companies, four contractors, two clients, one professional association representative, two municipality offices active in environmental protection and one large recycling companies in the region.

Table 1: List of the people involved in the data collection

Organisation	Interviews	Interviewees	Positions
Contractors	4	4	Project manager, site manager, production manager
Demolitions small - medium contractors	5	9	Project manager, site manager, production manager, sustainability manager
Large contractor subsidiary	2	3	Business developer manager
Recycling contractor	2	1	Business developer manager
Municipality (Gothenburg)	2	3	Environmental supervision unit
Construction Industry association	1	1	Officer in charge of WM
Clients/FM	2	2	Project managers
Total	18	23	

Data collection

The 18 semi-structured interviews were performed between 2017 and spring of 2019. They took place either at the interviewees' office in the company or at the construction site. The duration of these interviews ranged from forty-five minutes up to one and a half hour and 13 of 16 were conducted by two researchers. On four occasions, they were performed as group interviews with more than one representative of the companies. All the interviews were recorded and transcribed, before being transferred and analysed in NVivo according to the themes we developed in iteration with the theoretical framework on institutional work and the waste management literature. All participants were informed about the goal of the study and that their contribution is anonymous.

Besides, we have collected numerous written documents including professional guidelines, norms and certifications, companies' websites, renovation projects and quality control protocols, waste material descriptions, price lists and price calculations, and national and European governmental reports.

Empirical Material

Discourse as a maintenance strategy
In the way the interviewees talk about their professional activities, they mobilize a large number of similar elements to justify the actual practices and prevent the possibility to change. Here we list some of the main arguments:

The conservative reputation of the sector is still ranking high to account for the resistance to new practices. "- You must've heard about the 11th commandment in the construction sector? - That is? - This is the way we've always done it! - Followed by the 12th; We've never done it like that before!" (Officer in charge of waste management).

Another reoccurring argument in preventing improvement in sorting is the lack of space on site, especially within the urban city centre.

The central role of time and cost are mentioned by all the interviewees as the main barrier for adopting more rigorous waste management practices.

The work division between the different actors enables them to attribute the responsibility of taking initiative to improve RDWM to each other, i.e., the contractor blames the client and the subcontractor blames the contractor and so on.

They also blame the legislations for having too high demands in term of quality to enable the reuse of waste materials.

The demolition companies insist on the lack of clear demands regarding waste management, "In any formal document you send, no one will read the parts concerning waste and environment. You can include in the writing that: To whomever reads this, I will give you a cake, if you call this number. Nobody ever rings. That's the way it is, they never check that part." (SME Demolition contractor). A similar argument is mobilized for the work on site and the lack of interest for the waste as such; the contractors assess the quality of the demolition companies work, they claim, by the dismantling and cleaning of the facilities and not by the quality and quantity of the waste and what happens to it afterwards. Most of them also repeat that the selling of the waste is a side activity generating very low revenue and don't see a market potential for it.

Those arguments clearly identified in the interviews, were reflexively repeated during the workshop. Whenever solutions were proposed to improve the waste management processes, the demolition companies immediately reacted by mentioning one of these arguments to oppose the solution concluding with a: "all these sounds good but I have a business to run" (Demolition company manager).

Creating waste management institutions
The following section build mainly on two demolition companies that advocate for creation and one demolition company that demonstrates disruptive behaviour of the actual RDWM institution. However, we should not take for granted that the positions are clearly divided between actors.

In the most active company, the supporter of changes builds on the relabelling of the usual WM terms: "we do not demolish but deconstruct", material produced in WM is renamed product or resource "as by calling it waste, we've already accepted it as waste". Likewise, "the end of life understanding of WM" is substituted with a profit of a life cycle understanding where being waste in only viewed as a state in a non-ending transformation.

The actors of the three companies also insist on their responsibility as change agent and the necessity for all actors in the sector to question the current way of working as well as the distribution of tasks between the partners.

Most of the companies' part of our studies have invest in new low energy machines, equipment and vehicles or borrow specific machine instead of buying them.

Two of the front runner demolition companies have added sustainable WM as an integral part of the strategic agenda and incorporate sustainability information on different levels of the organization through forums and employee meetings.

These companies also offer WM training. They educate their own employees to more efficient and milieu friendly waste handling including health and safety, use of equipment and machines and organisation of transport. They offer similar programme to their customers selling their expertise as to create value for their customers.

They also network and actively contribute to trade conferences and seminars on the topic, presenting their new business model and best practices.

One of the companies for example is collecting waste from both its own and other companies' projects which are then sell further. This is perceived as positive for other companies as it reduces the cost for waste handling and offers the customer lower purchase costs for reused material and may even increase their revenue

Disrupting Waste Management

We find only one company which behaviour can be associated to disruption. This company, a subsidiary of one of the large contractors in Sweden, provides materials and services to the construction and civil engineering industry. The offer includes concrete, gravel and rock crushing, transport and construction machinery as well as environmental services such as recycling, land remediation and water treatment. They oppose clearly to the actual practices of collecting the different fractions on site but propose to collect material according to its reuse potential and the quantity produced. In doing so, they claim that material with a high recycling potential would be prioritised and its quality preserved. To focus on the quantity of material instead of putting an equal effort into all the different waste types, would optimised the recycling possibility and constitute a viable business model. But this necessitates that the construction companies themselves take charge of the material and can assess and 'ensure' the quality of their material. One of the demolition companies is using the example that they collect the waste, tests it, and if there isn't an issue, they resell it as construction material to other companies and avoid the additional waste handling fees for landfill material.

ANALYSIS

The following section analyses the empirical material according to the different forms of institutional work to maintain, create or disrupt the existing RDWM institution.

The maintenance category is presented in our material so far mainly through symbolic institutional work and the use of discourse to maintain the actual situation (Hampel *et al.,* 2017). The conservative actors are repeating the usual and taken for granted assertations about the construction sector and waste management: The sector cannot change, time and money rule, there is no space on site and no interest for the material produced. Their discourse contributes to maintain of the current institutions by defining the accepted structures, practices and beliefs. In mobilising the usual barriers, they argue for a generic understanding of the actual practices. The sector is

presented as one and indivisible, where contextualised solutions are not valued (Zilber, 2008). Building on these assertations, their position prevents any kind of new developments and may even describe the proposals for development as threatening their actual business, demonising the possibility of change (Lawrence and Suddaby, 2006).

Though these actors attend seminars and workshops, their attitude is critical towards ideas of new forms of practices and they often voice resistance. Nonetheless, they do recognise the necessity to adapt RDWM to the new sustainability demands but expect changes to be organised by other actors such as the state and municipalities and supported by new legislation.

The institutional work of actors in maintaining the current practices within the sector may not appear as explicit as of those trying to impose change. However, the daily work performed by these companies reinforces the actual practices and routines and reproducing continuously the current RDWM institution, their actions being intentional or not (Lawrence *et al.,* 2009).

There are a few actors performing creation work by offering new solutions and practices aligned with the current assumptions expressed in the industry guidelines and recommendations to achieve sustainability goals. Symbolic institutional work is mobilised when we see the actors renaming objects and processes. By developing a competitive labelling, the actors claim a new identity for RDWM enabling to change the perception and accordingly the practices (Hampel *et al.,* 2017).

The creation supporters actively engage in network of interests to share and diffuse their ideas, they participate in professional workshops and seminars and use professional media to share and legitimize their approach building on their own practices (Lawrence and Suddaby, 2006). In doing so, they participate to the spreading and normalisation of the new RDWM conceptualisation and practices. They also offer training in skills and knowledge necessary to support the establishment of the new institution (Lawrence and Suddaby, 2006).

Under the category disruption, we find arguments criticising and dismissing both the creation and maintenance strategy (Lawrence and Suddaby, 2006). This position rejects both the current RDWM institutions and the arguments for the new model. This company's discourse undermines both models by underlining the lack of financial viability of the existing institution and well as the new proposal. Building on a market logic where profitability is the only driver, the company proposes to redistribute the tasks and create new business models. They promote a type of change that goes beyond simply enforcing the current rules and instead questions the general perception and goals that are defined. Having developed one of the only successful construction recycling loops in Sweden, they participate in workshops, seminars and multidisciplinary research projects to share their views.

CONCLUSION

As a first step of research we have used the theory of institutional work and in particular the concept of creation, maintenance and disruption to identify actions mobilized in demolition company to account for the stability of the actual practices and may constitute barriers to the implementation of changes; as well as the ones indicating a possible creation of new practices or even disruption. Our study underlines that institutional work is performed using similar forms under the three

processes, however creation and disruption have in common the necessity of destabilising the existing institution to enable the creation of new ones.

Under the category maintenance we've gathered the 'status quo' arguments which repeat the commonly identified barriers. These barriers prevent any possibility of change and reproduce the actual institution.

Arguments are gathered under the creation section that are advocating for changes in practices that are aligned with the guidelines and the circular economy principles. They share the assumption that the implementation of those principles can be achieved.

Under the category disruption, we find the arguments criticising and dismissing both the creation and maintenance strategy. Here we find a position rejecting the creation and maintenance assumptions and propose to develop another paradigm to rethink how the RDWM can achieve sustainability.

The construction sector needs to take its responsibility to achieve the goal of the sustainable agenda. Our next step is to study what the actors do in their daily activities to shape their institutional context.

REFERENCES

Alzahrani, J I and Emsley, M W (2013) The impact of contractors' attributes on construction project success: A post construction evaluation, *International Journal of Project Management*, 31(**2**), 313-322.

Ajayi, S O, Oyedele, L O, Bilal, M, Akinade, O O, Alaka, H A and Owolabi, H A (2017) Critical management practices influencing on-site waste minimization in construction projects, *Waste Management*, 59, 330-339.

Ajayi, S O, Oyedele, L O, Bilal, M, Akinade, O O, Alaka, H A, Owolabi, H A and Kadiri, K O (2015) Waste effectiveness of the construction industry: Understanding the impediments and requisites for improvements, *Resources, Conservation and Recycling*, 102, 101-112.

Bosch-Sijtsema, P and Buser, M (2017) Construction and demolition waste management on the building site: A literature review, *In:* Chan, P W and Neilson, C J (Eds) *Proceeding of the 33rd Annual ARCOM Conference*, 4-6 September 2017, Cambridge, UK, Association of Researchers in Construction Management, 269-278.

Buser, M and Bosch-Sijtsema, P (2018) Attributing value to waste: The difficult road to efficient waste management for renovation projects, *In:* Gorse, C and Neilson, C J (Eds.), *Proceedings 34th Annual ARCOM Conference*, 3-5 September 2018, Queen's University, Belfast, UK Association of Researchers in Construction Management, 119-128.

Bresnen, M (2017) Being careful what we wish for? Challenges and opportunities afforded through engagement with business and management research, *Construction Management and Economics,* 35(**1/2**), 24-34.

Chan, P (2018) Change and continuity: What can construction tell us about institutional theory? *In:* D J Sage and C Vitry (Eds.) *Societies Under Construction: Geographies, Sociologies and Histories of Building*. Cham: Springer International Publishing.

European Commission (2016) *Construction and Demolition Waste Management in Sweden*. Available from http://ec.europa.eu/growth/content/eu-construction-and-demolitionwaste-protocol-0_en [Accessed 2nd September 2015].

Gluch, P and Bosch-Sijtsema, P (2016) Conceptualizing environmental expertise through the lens of institutional work, *Construction Management and Economics*, 34(**7/8**), 522-535.

Gluch, P and Svensson, I (2018) On the nexus of changing public facilities management practices: Purposive and co-creative actions across multiple levels, *Construction Management and Economics*, 36(**5**), 259-275.

Greenwood, R, Oliver, C, Suddaby, R and Sahlin-Andersson, K (2008) Introduction to the Sage handbook of organizational institutionalism, *In:* R Greenwood, C Oliver, K Sahlin and R Suddaby (Eds.) T*he SAGE Handbook of Organizational Institutionalism*. London: Sage publications.

Grin, J, Rotmans, J and Schot, J (2010) *Transitions to Sustainable Development: New Directions in the Study of Long-Term Transformative Change*. New York: Routledge.

Hampel, C E, Lawrence, T B, Tracey, P, Greenwood, R and Oliver, C (2017) Institutional work: Taking stock and making it matter, *In:* R Greenwood, C Oliver and T B Lawrence (Eds.) *The Sage Handbook of Organizational Institutionalism*. London: Sage Publications.

Hardie, M, Miller, G and Khan, S (2011) Waste minimisation in office refurbishment projects: An Australian perspective, *Open Waste Management Journal*, 4, 21-27.

Jin, R, Yuan, H and Chen, Q (2019) Science mapping approach to assisting the review of construction and demolition waste management research published between 2009 and 2018, *Resources, Conservation and Recycling*, 140, 175-188.

Lawrence, T B, Suddaby, R and Leca, B (2011) Institutional work: Refocusing institutional studies of organization, *Journal of Management Inquiry*, 20(**1**), 52-58.

Lawrence, T B and Suddaby, R (2006) Institutions and institutional work, *In:* S R Clegg, C Hardy, T B Lawrence and W R Nord (Eds.) *Sage Handbook of Organization Studies, 2nd Edition*. London: Sage, 215-254.

Lawrence, T B, Suddaby, R and Leca, B (2009) Introduction: Theorizing and studying institutional work, *In:* B Leca, R Suddaby and T B Lawrence (Eds.) *Institutional Work: Actors and Agency in Institutional Studies of Organizations*. Cambridge: Cambridge University Press.

Li, M and Yang, J (2014) Analysis of interrelationships between critical waste factors in office building retrofit projects using interpretive structural modelling, *International Journal of Construction Management*, 14(**1**), 15-27.

Lieftink, B, Smits, A and Lauche, K (2019) Dual dynamics: Project-based institutional work and subfield differences in the Dutch construction industry, *International Journal of Project Management*, 37, 269-282.

Lu, W and Yuan, H (2011) A framework for understanding waste management studies in construction, *Waste Management*, 31(**6**), 1252-1260.

Micelotta, E R and Washington, M (2013) Institutions and maintenance: The repair work of Italian professions, *Organization Studies*, 34(**8**), 1137-1170.

Park, J and Tucker, R (2017) Overcoming barriers to the reuse of construction waste material in Australia: A review of the literature, *International Journal of Construction Management*, 17, 228-237.

Patterson, J J and Beunen, R (2019) Institutional work in environmental governance, *Journal of Environmental Planning and Management*, 62(**1**), 1-11.

Sezer, A A (2017) Factors influencing building refurbishment site managers' waste management efforts, *Journal of Facilities Management*, 15(**4**), 318-334.

Suddaby, R and Greenwood, R (2009) Methodological issues in researching institutional change *In:* Buchanan, D and Bryman, A (Eds.), *The SAGE Handbook of Organizational Research Methods*. London: Sage Publications,177-195.

Udawatta, N, Zuo, J, Chiveralls, K and Zillante, G (2015) Improving waste management in construction projects: An Australian study, *Resources, Conservation and Recycling*, 101, 73-83.

Urup, L (2016) *Integrated Design-Build Management: Studying Institutional Processes to Understand Project Coordination and Performance*, PhD thesis, Department of architecture and civil engineering, Chalmers University of Technology.

Wu, Z, Ann, T and Shen, L (2017) Investigating the determinants of contractor's construction and demolition waste management behaviour in Mainland China, *Waste Management*, 60, 290-300.

Zilber, T B (2008) The work of meaning in institutional processes, *In:* R Greenwood, C Oliver, K Sahlin and R Suddaby (Eds.) *Handbook of Organizational Institutionalism*, London: Sage, 150-169.

Zilber, T B (2009) Institutional maintenance as narrative acts, *In:* T B Lawrence, R Suddaby and B Leca (Eds.) *Institutional Work: Actors and Agency in Institutional Studies of Organizations*. Cambridge: Cambridge University Press, 205-235.

LÉVINAS' ETHICS IN PRACTICE: A CONSTRUCTION CONTRACTOR'S ACCOUNT

Henning Grosse[1]

School of Business and Technology, University of Gloucestershire, Oxstalls Lane, Longlevens, Gloucester, GL2 9HW, UK

This autoethnographic study offers a practitioner's view of ethical problems in construction management. Using Lévinas' thoughts on one's decisions and their consequences, I demonstrate their relevance and implications for construction management. The ethical issues I faced brought me regularly to the limits of guiding ethical principles. But Lévinas offers a way forward by deliberately moving beyond principles and prioritising the encounter of the Other. Yet my positivist engineering training made it particularly difficult to accept thinking beyond ontological categories. While I reflect on being perplexed, insecure and struggling, I give an insider account of the application of postmodern ethics and the consequences for me as a practitioner in the construction industry. Doing so, I address two missing perspectives in construction management research. I showcase a distinctively postmodernist perspective on management ethics and draws extensively on other disciplines. At the same time, I ground my work in practitioner experiences. Hence connecting the conceptual discussion about ethics in construction management research strongly to practice-relevant issues. I offer different ways of thinking about ethical dilemmas and passages out of resulting deadlocks. Therefore, this study might support practitioners and academics facing similar issues.

Keywords: Autoethnography, ethics, Lévinas, practitioner research

INTRODUCTION

In my position as a manager in the construction industry, I must make decisions on a daily basis. Each of these decisions has an impact on others and therefore, ethical aspects. To address these aspects, managers have to consider and comply with rules and guidelines.

Rules and guidelines might serve as a basis, yet often I experience them as insufficient to take the ethical decisions because one must move beyond them to act ethically. Therefore, I seek to understand these problems in light of Lévinas' thought. His thinking is founded in Plato's good beyond being (1997) and finds its implications in postmodern ethics (Bauman 1993). Lévinas essentially says ethics must originate in the encounter with another human being. Therefore, he argues, ethics - the concern or responsibility for the other - comes first always. Any principle or concept must derive from facing the other (Lévinas 1961, 1974). Using that understanding, I will provide some suggestion about how to think about ethical aspects of managerial decisions.

I am interested in ethics since I dealt extensively with Lévinas' work. He is said to be one of the most influential French philosophers of the 20th century (Critchley 2002).

[1] hgrosse@glos.ac.uk

Grosse, H (2019) Lévinas' Ethics in Practice: A Construction Contractor's Account *In:* Gorse, C and Neilson, C J (Eds) *Proceedings of the 35th Annual ARCOM Conference,* 2-4 September 2019, Leeds, UK, Association of Researchers in Construction Management, 94-103.

He is strongly influenced by the phenomenology of Husserl and Heidegger and influenced himself, Derrida and Sartre, among others. His thoughts revolve predominantly around the ethical relation between the self and the unknowable Other (human being). A central aspect of his thought is ethics prior to rational thought (Lévinas 1961, 1974) therefore, ethics and responsibility - the way Lévinas uses the terms - go beyond what one is accountable for. In the following, I reflect on my personal experience using his ideas. Doing so, I seek to demonstrate the limits of general rules and guideline in order to act ethically sound in business relations.

The autoethnographic material from my business practice will illustrate the ethical aspects of decisions I had to make and will demonstrate the problems general rules and guidelines pose. Using examples, I will further clarify Lévinas thought. Doing so, I introduce a discussion about postmodern ethics, which is still missing in construction management research.

RESEARCH APPROACH - AUTOETHNOGRAPHY

The research approach I am pursuing here is twofold on the one hand I write autoethnography and reflect on my experiences using Lévinas' thought as mirror or axis. Autoethnography is a branch of ethnography. Ethnographers participate and observe their natural or real-world research setting. They write fieldnotes about their observations and analyse these notes.

During the last years, Ethnography gained some momentum in construction management research as Pink, Tutt and Dainty's edition (2013) and more recent works show (e.g., Koch and Schultz 2018, Löwstedt 2015, Oswald *et al.,* 2018). Autoethnographies are, however, much rarer in construction management (e.g., Kanjanabootra and Corbitt 2016, Thiel 2005, 2010).

Autoethnographers write about their own personal environment and often focus on their own feelings and emotions (Ellis and Bochner 2000, Ellis, Adams and Bochner 2011). I write notes about my experiences within my business. Often, I sit down in the evening and start to write about what happened during the day. I focus on events that grabbed my attention, the ones that seem important to me. Hence, I rely on my sense of significance (Emerson, Fretz and Shaw 2011).

While writing fieldnotes, I already start to analyse them. I draw connections to previous events, perhaps earlier fieldnotes or even events long past. In this way, I use writing as a form of inquiry (Richardson and Adams St. Pierre 2005). At the same time - I may say almost inevitably - I begin to reflect on my experiences in the light of Lévinas' thought. Often, I start writing by setting me a minimum target word count (500 words). That works as a sort of warm-up. Most the time I exceed and write much more. I begin by describing a situation, but most the time meander in a sort of nomadic writing exploring and reflecting on different aspects (Adams St. Pierre 1997). Using this approach, I explored different aspects of my life as a business owner, one of which is the ethical aspect of my role.

Limits of Rules and Guidelines

Research in construction management used, for example, the notions of "ethical concepts" (Ho Man-Fong and Ng Chi-Wai 2003), "ethical principles" (Ayers *et al.,* 2013), "ethical framework" or "ethical infrastructure" (Vee and Skitmore 2003) as a synonym for guidelines and rules. Often these guidelines are founded on a diverse range of models of decision making (see Ho Man-Fong 2011). Yet, in my professional role, I often wrestle with such rules and guidelines since they are not

sufficient. Therefore, I explore what surpasses these concepts using Lévinas. Such an exploration of ethics in construction management, which draws on postmodern ethics (e.g., Bauman 1993, Lévinas 1974), is to my knowledge still lacking. Hence, I use Lévinas' thought to take the discussion in construction management beyond the borders of concepts and rules.

To demonstrate the practical relevance of this discussion, I use examples from my PhD thesis, I wrote about my own construction business (Grosse 2018). The following situation (fieldnote in italics) demonstrates how rules - in this case, our contract - fail to offer help dealing with ethical aspects of due decisions. Although my staff member had the contract to hand, he could not help but having doubts about the ethical aspect of what contract prescribed.

Pricey Bricks

An architect, I had known for almost my entire business life, called me and asked for help with a project. The contractor, her client commissioned, could not finish some work on time. So, she asked me to finish part of the job. One part of it was exchanging old broken or defect bricks from an early 20th century façade. We agreed on a price for a single replaced brick by a new brick. In the end, we multiplied the estimated number of bricks to be replaced by the price per brick and got the sum of the contract.

We started to work, and after some time it turned out that the price was far too high. The actual cost of replacing a brick was only a fraction of the price in the contract. My site manager when he wrote the invoice offered a substantial discount on the price for the brick.

When we discussed the issue, he said something like: 'Of course, we want to make a profit, but that seemed too much. We can't do that. We're still making a good bargain, but 'let's keep the church within the village.' (Grosse 2018)

'Keeping the church within the village' is a metaphor Germans use if they feel an action is inappropriate - literally, a church belongs in the village not outside of it. Although replacing the bricks was only a minor job on this huge project, I use this example to show the ethical limits of our contractual provisions. We - as company - could have claimed the full price for each brick my workers replaced by referring to the contract. Yet, my site manager expressed something that goes beyond the contract - to him (and to me too) it felt not okay to charge the full price. However, it is difficult to describe the feeling we had. Therefore, I use the metaphor of 'keeping the church within the village'. It represents quite well that the price for the replaced bricks felt too high, yet it was not determined what would be an appropriate price. The metaphor is of somewhat vague or ambiguous nature. It does not determine what is right or appropriate. Still, it signals that something does not feel right or appropriate. This ambiguity nicely fits into my understanding of ethics as they are not clear-cut right-wrong decisions. There is often a spectrum in which an appropriate choice lies.

One could contemplate for endlessly about pricing and profit margins. Certainly, one would arrive at the point thinking 5 to 10 % of the turnover would be an appropriate profit margin in this case. But what about the risk I have taken beforehand. If all turns out well - as it did in the example above - a moderate profit margin seems appropriate but how does one factor in riskier ventures? There might be little assistance available when things go wrong. Hence, more risk demands higher

margins. What if one miscalculates the risk involved? I doubt that there is a calculation which might suit in all circumstances. My or my company's situation is different in each new contract, and the clients' or project partners' situation is different too. Therefore, some guidelines will be helpful, yet these guidelines must not be hammered in stone but should be scrutinised in each new situation.

However, general rules and guidelines have a special attraction. First, an engineer myself, I was trained to distinguish right and wrong - one can say whether there is a sufficient amount of iron in a concrete beam. That is how engineering professionals are used to making decisions, yet ethical decisions are different in nature from technical choices. But, applying guidelines limit their discretion and thinking only in concepts similarly stifles the academic debate too. There is a need to go beyond concepts for academic and managers.

And second, it would have been so convenient to refer to the contact in the case above. I wonder whether it would have been easier for him to charge the full price for each brick and to make a lot of money. He could have referred to the contract, and that would have legitimised him. In some regard, it would have been for him the comfortable way to go. The only obstacle was his doubts about the appropriateness of the pricing. If he could have suppressed his doubts, it would have been a comfortable and easy way. But he could not. The doubts he had were too strong to suppress.

> Forget your perfect offering. There is a crack in everything. That's how the light gets in (Cohen 1992)

The crack in my example above is his uncomfortable feeling he expressed using the metaphor. The crack essentially let the ethical light in. Following up on the doubts he had, and questioning guidelines and rules are essential and inevitable parts of ethically taking decisions. To understand why this scepticism is so important to ethically taking decisions, I draw on Lévinas' work. One aspect of his thinking is nicely described by Critchley (2015: 11):

> I'm suggesting here that we think of Levinas' work […] as drama […]. [T]he core of tragedy is the experience of moral ambiguity, where justice is on both sides and one is swayed one way and then the other. The lesson of tragedy[..] consists in the ability to bear moral ambiguity. This means that justice is not one but is at least two, and the experience of tragedy is watching one conception of justice turn into it's opposite and then turn inside out. Justice is conflict.

I will try to translate this conflict, this 'moral ambiguity' into my example. On the one hand, the contract prescribed the price and made a case for earning a lot of money. It is, of course, the job of the site manager to manage building sites efficiently and as a result to generate profit. The whole business aims at earning money. So why having second thoughts? Yet, the ambiguity surfaces through his use of the 'church within the village' metaphor. It clearly signals something feels not okay. Hence, saying it, he opens a space for interpretation. It is a deconstructive move; it abandons a rule and offers freedom for a responsible decision (Derrida 1992). Now we had to weight different arguments against each other.

Abandoning rule is almost like opening Pandora's box. One has to start thinking about further implications. The looming profit could have helped the company in various ways (buying new equipment to make work easier, paying workers more, easing some pressures, or just as a provision for economic difficulties). There were a lot of reasons available to legitimise (contract) and justify (further implications) the high price for replaced bricks. Generating profits is not a bad thing after all (I am supposed to say that because I run a business). One can easily see that not charging the full price had

implications beyond simply making more money. For me - as the owner of the business - it is easier to make decisions because I have much more discretionary freedom than, for example, a manager in a big cooperation entangled in multiple dependencies and reporting to several seniors.

> The comedy begins with the simplest of our movements, each of which carries with it an inevitable awkwardness. In putting out my hand to approach a chair, I have creased the sleeve of my jacket. I have scratched the floor; I have dropped the ash from my cigarette. In doing that which I wanted to do, I have done so many things I did not want. The act has not been pure, for I have left some traces. In wiping out these traces, I have left others. Sherlock Holmes will apply his science to this irreducible coarseness of each of my initiatives and thereby, the comedy may well turn tragic. (Lévinas 1951: 4)

The decision had further consequences for my company and, of course, had ramifications for our employer too. Since the employer was a big company and our part only tiny within the context of this large project, the ethical dimension of our decision was not that significant for the employer.

But on the other hand, it still felt too much to charge the full price. A lower price would have been enough to serve the company sufficiently. A very difficult question arises: What is enough profit? How much do I need to make a living from? Lévinas is here a bit vague.

> Only a subject that eats can be for-the-*other or* can signify. (Lévinas 1974: 74)

The following example demonstrates which impact my decisions may have on others far better. At the same time, it illustrates the issue of 'having eaten' and so being able to share more.

The Cooperative

We worked on a social housing project. The owners of the estate, a five-floor building in Berlin with space for some 20 families, was a cooperative. The ones who wanted to live in this house were obliged to be members of this cooperative and did not actually own one flat but rather the right to live in one for rather low rent. Hence, they had shared responsibilities and some advantages. Apart from that, they had to do quite a lot of building work by themselves to keep the cost of constructing the buildings low.

When we came to the end of the project, it turned out that we had to charge them more than our initial quotation included, since we had to do more work than initially thought.

We sent the architect we worked before our final bill, and he gave his approval. But then the money did not come. We had sent them a couple of bills before, and they never paid late. So, I was a bit surprised. One day I called the architect because he had close ties to the cooperative and asked why they did not pay. The problem it turned out was that they ran out of money. The architect recommended to call the cooperative directly and gave me the number of the accountant. I did call. The accountant quite frankly admitted that they were short of money and that she could not pay.

One has to know that the families living in the house are low middle class - not really poor and in need but also by far not in the position to buy a detached house in Berlin's surroundings. They are working class. They can afford to pay the monthly rent and may have paid some to the cooperative. But apart from that their financial situation appears to be strained.

During the phone call, I raised that there is a monthly income on the side of the cooperative - the rents will come each month. So, I suggested that we find an agreement where each month a small amount of money is paid, and I offered them a very low interest. She discussed it with the board of the cooperative, and they agreed to my proposal.

Of course, I could have insisted on my right to get paid immediately. But at this moment that seemed not fair to me. No question, I wanted to get my money. But I did not need it immediately at that time. So why should I 'point a gun at their chest?' I got my money with quite some delay, on top of some interest, and they were happy too. (Grosse 2018)

In case I would have insisted on immediate payment, I would have caused the cooperative massive problems. But I did not need the money at this moment. I was sure that they would be able to serve the debts by paying monthly instalments. It just took them some time. One could read this situation as follows: I had eaten enough - my needs were satisfied (Lévinas 1961) - at least for the time being. Hence, I was able to share. Insisting on immediate payment would have had an impact on the members of the cooperative and their families. These were the very people I met during a barbeque on the building site. I had a lovely evening with them and their kids. I just could not cause them so much hardship.

The Other

I am not sure whether the architect in the first example had some idea about how many hours of work we needed to replace the bricks. It is, of course, an aspect of whether or not the partner we are interacting with has an idea about our costs in relation to the prices we charge. Here first surfaced one important aspect of ethical acting - which is that we act in the face of a human other. This aspect gained much more importance in my dealings with the cooperative.

The cooperative members and their kids were the 'Other' as Lévinas (1961) calls them. I experienced them as human Others. I literally faced them. This distinguishes the two examples. In the first example, I only knew the architect personally but not the employer, whereas in the second example, I knew the persons behind the cooperative. One may relate this the Bauman's distinction between mask and faces. I encounter a human Other by his or her face whereas in the distance, this face becomes a mask. The face of the Other is immediately and unmitigated present to me. Only when I distance myself, the face becomes a mask which I can compare. (Bauman 1993).

When we face the Other, we are merely responding to him. The Other stays a stranger, and we cannot comprehend the Other's otherness. This relation is never equal, and the Other never becomes an object. This distinguishes Lévinas form, for instance, Martin Buber who allows for an equal and distanced relationship. In which the I-Thou relation evolves. Subsequently, the Thou becomes It and the I become a Thou (Buber 1958). However, for Lévinas, the Other is always more than me.

We recognise the Other and interact with him through 'saying'. Levinas terms 'saying' as a preconscious interaction with the Other distinct from the 'said'. Saying is the momentary, elusive, subjective act of encountering the Other; saying is signifying. The said is what is the saying produces: rational thought, concepts and abstractions. In other words, the saying resembles the infinite Otherness of the other human being, and the said is the reduction of the encounter with the Other into my

limited categories (Lévinas 1974). "For Levinas, Saying has its own meaning, quite separate from anything that might be communicated by the Said." (Davis 1996: 77) "Lévinas distinguishes between language in its expressive or ethical function, called 'saying,' and language in its theoretical or ontological function, the 'Said.'" (Atterton and Calarco 2005: 55) They further explain that "language cannot be reduced to a merely instrumental function as a tool for transmitting information. Language also has an ethical dimension that is irreducible to what is said." (Atterton and Calarco 2005: 55). This ethical dimension is saying.

This ethical dimension of saying is closely related to Lévinas' understanding of responsibility. Similarly, to Derrida (1992) Lévinas locates responsibility beyond rationality. For him, we are responsible prior to consciousness, before we rationally think, because our rationality, our consciousness is grounded in the encounter with the Other. The Other(s) are essential to constitute our self. (Lévinas 1961, 1974) Our world would dissolve without the "community of speakers" on which we rely. "At the heart of this community […] is the ethical relation." (Large 2015: 44)

Lévinas places ethics as first philosophy and anchors ethics in the pre-conceptional encounter of a human Other and, therefore, safeguards philosophy against inhumanity (which he experienced as European Jew during Nazi rule). He strongly relates this thinking to Plato's good beyond being (Plato 1997). The Good is beyond ontological categories and is essentially ethical saying. Encountering the Other challenges and questions our said, our very self. Encountering the Other, I have to respond to him or her - I am supposed to act responsibly towards this person.

Since I met the persons behind the cooperative, I interacted with them by saying. Therefore, the ethical dimension of our interaction surfaced. The ethical dimension here clearly went beyond what the rationale of the contract dictated. That is why the ethical aspect had much more significance with the cooperative in contrast to the unknown employer. I had faced the Other - in person - there was not a mask behind which these persons were hidden. In the case of the cooperative, it was almost inevitable for me to share and therefore act responsibly towards them because I had already 'eaten enough' (Lévinas 1974).

One may argue that it was easier for me to do so since I was not in need myself. I could afford to be paid late or, as in the case here, by monthly instalments. I had already eaten and had enough to eat. It would have been hard for me to deny the cooperative assistance. I felt compelled to help. I was urged to offer my assistance. It relates to sharing, to "snatching the bread from one's mouth" (Lévinas 1974: 74)

Still, I wonder "What would other contractors be doing? Wouldn't they use this opportunity to generate a good profit? Isn't it naïve to give away the money?" In some sense it certainly is. Would I get more money in case my prices would not cover my cost, or would I have to shoulder the bill on my own? Probably, I would be left alone with overrunning costs. Still, it does not feel appropriate to make such a big profit.

However, as I argued above, ethics is first philosophy. It is not grounded in rationality, there is no reason, no rationale in favour of acting ethically. Ethics is an end to itself. But cannot rationally argue against acting ethically. Not our fear of bad reputation or coercion forces us to act ethically - it is just because we want to do so. Ethics cannot be a means to an end. Nevertheless, only one who "eats can be for-the-other" (Lévinas 1974: 74). The difficult question remains, what does it mean to have enough?

> Goodness consists in taking up a position such that the Other counts more than myself. (Lévinas 1961: 247)

One may argue that drawing on Lévinas, I argue for self-sacrifice. But I do not. I set out Lévinas thought as a guiding principle. I argue in favour of assuming responsibility. A Responsibility that "does not primarily refer to something which has said and done but rather to something which has to be said and done." (Waldenfels 1995: 41) To be receptive to the urge to help the Other who is in need (Caputo 2000) is what I am arguing for within the bound of providing for one's own needs.

> I think there's also something deep here, in the sense in which I think that the correct philosophical attitude is to be at war with yourself. If you're not, you're either not being honest or you're not doing good work. (Critchley 2015: 17)

To act ethically cannot be comfortable. Ethics is this urge to say and do "which ought to be said and done" (Waldenfels 1995: 41), it is the recurring scepticism, the responsibility which overwhelms me (Lévinas 1974). It is a constant struggle. I must decide which Other I serve first. To which Other do I speak. As Lévinas said in an interview, "I am led to compare the faces, to compare two people. Which is a terrible task." (Wright, Hughes and Ainlley 1988: 174)

Following a rule or guideline is, of course, easy and comfortable. From my personal experience as a trained civil engineer, I am used to applying rules and regulations. They make perfect sense when it comes to structural designs. And I perfectly understand the difficulties one faces when questioning and perhaps abandoning rules. However, facing one's responsibility - beyond what one is accountable for - is the only way to act ethically.

SUMMARY

These two very simple examples demonstrate how managers in the construction industry are trapped within multiple interpretations of the same event. It is never one, seldom two but often many different perspectives on a matter that demands a decision. This is one aspect of why general guidelines and rules alone are so problematic. Further, the implications of decisions are far-reaching - way beyond the problem at hand - and cannot be reflected in general rules and guideline.

One may argue that ethical guidelines are necessary to do business in general, which also applies to construction management. I do not challenge this assertion; however, I add that guidelines are not sufficient. Even more, I emphasise that guidelines cannot be sufficient for ethical management because ethics precede every concept. Hence, an ethically facing the other - i.e. sensing or feeling that what one is about to do does not appear appropriate - must lead to a questioning of rules and guidelines.

One may argue that this thinking is of little help because it leaves space for arbitrary decisions. This is certainly the case, yet it leads me to a central point of my research: ethics is first philosophy. The ethical decision cannot be grounded in general principles or rules. An ethical judgement must embrace the human other by responding responsibly and not technocratically. This response must contain a responsibility which not founded in any principle but in genuine care for the Other.

REFERENCES

Adams St Pierre, E (1997) Circling the text: Nomadic writing practices (Exploratory writing as research technique), *Qualitative Inquiry*, (**4**), 403-17.

Atterton, P and Calarco, M (2005) O*n Lévinas Wadsworth Philosophers' Series*. Belmont, CA: Thomson Wadsworth.

Ayers, G F, Culvenor, J, Sillitoe, J and Else, D (2013) Meaningful and effective consultation and the construction industry of Victoria, Australia. *Construction Management and Economics*, 31(**6**), 542-67.

Bauman, Z (1993) *Postmodern Ethics*. Malden, MA: Blackwell.

Buber, M (1958) *I and Thou*. New York, NJ: Charles Scribner's Sons.

Caputo, J D (2000) The end of ethics, *In:* Lafollette, H (Ed.) *The Blackwell Guide to Ethical Theory First Edition*, Malden, MA: Blackwell,111-28.

Cohen, L (1992) *Anthem*. *In:* The Future: Columbia Records.

Critchley, S (2002) Introduction, *In:* S Critchley and R Bernasconi, (Eds.) *The Cambridge Companion to Lévinas*. Cambridge: Cambridge University Press, 1-32.

Critchley, S (2015) *The Problem with Lévinas*. Oxford, UK: Oxford University Press.

Davis, C (1996) *Lévinas: An Introduction*. Notre Dame, IN*:* University of Notre Dame Press.

Derrida, J (1992) Force of law: The mystical foundation of authority, *In:* D Cornell, M Rosenfeld and D G Carlson (Eds.) *Deconstruction and the Possibility of Justice*. London, UK: Routledge, 3-67.

Ellis, C and Bochner, A P (2000) Autoethnography, personal narrative, reflexivity: Researcher as subject, *In:* N K Denzin and Y S Lincoln (Eds.) *Handbook of Qualitative Research 2nd Edition*, Thousand Oaks, CA: Sage, 733-68.

Ellis, C, Adams, T E and Bochner, A P (2011) Autoethnography: An overview Forum, *Qualitative Social Research*, 12(**1**).

Emerson, R M, Fretz, R I and Shaw, L L (2011) *Writing Ethnographic Fieldnotes Second Edition*, Chicago guides to writing, editing and publishing, Chicago, Il: The University of Chicago Press.

Grosse, H (2018) *Investigating Trust in the German Construction Industry: A Contractor's Autoethnographic Exploration of Trust and Lévinas*, School of Business and Technology, University of Gloucestershire.

Ho Man-Fong, C (2011) Ethics management for the construction industry: A review of ethical decision-making literature, *Engineering, Construction and Architectural Management*, 18(**5**), 516-37.

Ho Man-Fong, C and Ng Chi-Wai, V (2003) Quantity surveyors' background and training and their ethical concepts, conceptions and interests' considerations, *Construction Management and Economics*, 21(**1**), 43.

Kanjanabootra, S and Corbitt, B (2016) Reproducing knowledge in construction expertise: A reflexive theory, critical approach, *Construction Management and Economics*, 34(7-8), 561-77.

Koch, C and Schultz, C S (2018) The production of defects in construction - An agency dissonance, *Construction Management and Economics*, 1-14.

Large, W (2015) *Lévinas' Totality and Infinity: Reader's Guide*. London, UK: Bloomsbury.

Lévinas, E (1951) Is ontology fundamental? (Atterton, P, Noctor, G and Critchley, S, Trans.) *In: A* T Peperzak, S Critchley and R Bernasconi (Eds.) *Basic Philosophical Writings*, Bloomington, In*:* Indiana University Press, 1-10.

Lévinas, E (1961) *Totality and Infinity*. Pittsburgh, PA: Duquesne University Press.

Lévinas, E (1974) *Otherwise Than Being, or, Beyond Essence*. Pittsburgh, PA: Duquense University Press.

Löwstedt, M (2015) 'Taking off my glasses in order to see': Exploring practice on a building site using self-reflexive ethnography, *Construction Management and Economics*, 33(**5/6**), 404-14.

Oswald, D, Sherratt, F, Smith, S D and Hallowell, M R (2018) Exploring safety management challenges for multi-national construction workforces: A UK case study, *Construction Management and Economics*, 36(**5**), 291-301.

Pink, S, Tutt, D and Dainty, A (2013) *Ethnographic Research in the Construction Industry First Editio*n. Abingdon: Routledge.

Plato (1997) Phaedrus (Nehamas, A and Woodruff, P, Trans.) *In:* J M Cooper and D S Hutchinson (Eds.) *Complete Works*. Indianapolis, In*:* Hackett Publishing, 506-56.

Richardson, L and Adams St Pierre, E (2005) Writing: A method of inquiry, *In:* N K Denzin, and Y S Lincoln (Eds.) *The Sage Handbook of Qualitative Research, Third Edition*. Thousand Oaks, CA: SAGE, 959-978.

Thiel, D J (2005) *Builders: The Social Organisation of a Construction Site*, Department of Sociology, University of London: London School of Economics and Political Science.

Thiel, D J (2010) Contacts and contracts: Economic embeddedness and ethnic stratification in London's construction market, *Ethnography*, 11(**3**), 443-71.

Vee, C and Skitmore, C (2003) Professional ethics in the construction industry, *Engineering, Construction and Architectural Management*, 10(**2**), 117-27.

Waldenfels, B (1995) Response and responsibility in Lévinas, *In: A* T Peperzak (Ed.) *Ethics as First Philosoph*y. London, UK: Routledge, 39-52.

Wright, T, Hughes, P and Ainlley, A (1988) The paradox of morality: An interview with Emmanuel Lévinas, *In:* R Bernasconi and D Wood (Eds.) The provocation of Lévinas: Rethinking the other, London, UK: Routledge, 168-80.

INTERACTIVE SHAPING OF EXPERTISE: THE PLAY BETWEEN HOUSE-OWNER AND SME CONTRACTORS NEGOTIATING RENOVATION

Martine Buser[1], Veronica Carlsson and Christian Koch

Division of Construction Management, Department of Architecture and Civil Engineering, Chalmers University of Technology, SE-412 96 Gothenburg, Sweden

Most of the single-family houses, which represent a large part of the existing building stock in Sweden, perform poorly when it comes to energy efficiency and sustainability. Nevertheless, during the renovation of these houses the focus is often directed towards comfort and design. Comfort concerns or not, the first encounter between the house-owner and the contractor in charge of the renovation is an occasion where energy efficiency solutions could be introduced. In the retrofit process the main partner and consultant is often a SME contractor. In principle the SME contractors' expertise on sustainable solutions could influence the house owners' choices regarding the improvements to be made. But it is unclear how this expertise manifests itself during the interaction, moreover the house owner is also claiming expertise on his/her own house. Building on Goffman micro-sociological concepts, this paper illustrates how the expertise is dynamically built during the interactions between the house owner and SME contractor. Goffman's approach enables us to view this interaction as a public performance where the two actors demonstrate, contest, challenge and finally accept the role of expert. Expertise is therefore something shaped during the interaction, rather than a given attribute. The empirical material consists of 18 observations between house-owner and SME contractor interactions as well as 16 workshops with contractors, mainly carpenters and electricians, interested in developing new approaches to retrofit. The results show how the expertise is negotiated and embodied and how these interactions are framing the content of the renovation.

Keywords: interactional expertise, energy renovation, Goffman, owners, Sweden

INTRODUCTION

There is a common understanding that single-family houses represent a large potential for sustainable renovation. When defining the scope of renovation, one could anticipate that retrofit measures, either reducing consumption of energy or even installing microgeneration of energy would occur. However, most of the renovation projects do not encompass elements of retrofit. In principle, the expertise of small and medium enterprises SME contractors such as carpenters, bricklayers, electricians and others, to define sustainable solutions could influence the house owners' choices regarding the scope and quality of improvements to be made. But it is unclear how this expertise manifests itself during the interaction with their customer, moreover the house owner is also claiming expertise on his/her own house (Buser and Carlsson

[1] buser@chalmers.se

Buser, M, Carlsson, V and Koch, C (2019) Interactive Shaping of Expertise: The Play Between House-Owner and SME Contractors Negotiating Renovation *In:* Gorse, C and Neilson, C J (Eds) *Proceedings of the 35th Annual ARCOM Conference,* 2-4 September 2019, Leeds, UK, Association of Researchers in Construction Management, 104-113.

2017). The aim of the present paper is thus to ask how expertise is shaped in the interaction between house owners and SME craftsmen. Here expertise is understood as a public performance where the actors demonstrate, negotiate, challenge and finally accept the role of expert and how the context of this performance may challenge the potential for retrofit to view expertise as something shaped during the interaction, rather than a given attribute (Williams *et al.,* 1998). We adopt a predominantly interpretative approach drawing on Goffman dramaturgical concepts. The material for the paper stems from a PhD. dissertation of the third author (Carlsson 2017).

As most of the renovation projects do not encompass elements of energy retrofit, scholars have concentrated their research to account for this lack of retrofit. Their studies mostly document what are the barriers to retrofit and focus on the actors involved and the decision processes underlining the choices of interventions for retrofit, renovation or decoration of houses (Vlasova and Gram-Hanssen 2014, Archtnicht and Madelner 2014, Haines and Mitchell 2014). The actors usually identified in these processes include: house owners, craftsmen, and sometimes technical experts (Owen and Mitchell 2015; de Wilde and Spaargaren, 2019). The barriers identified for the house owners encompass the lack of information and technical knowledge regarding retrofit (Mortensen *et al.,* 2014); their investments in other forms of renovation targeting comfort, lifestyle or aesthetic (Risholt and Berker 2013) the possibility to carry the work themselves instead of hiring a contractor (Risholt and Berker, 2013); or the perception that renovation is a burden (Mlecnik, Kondratenko and Haavik, 2012, Fawcett 2014); as well as too slow payback periods for the cost of the operations (Galvin 2014). Besides, the lack of regulatory requirements and incentives regarding the energy standard in Sweden (Mahapatra *et al.,* 2013, Niskanen 2018) as well as the owners' insufficient financial assets and resistance to loans are also mentioned as a hinder to retrofit (Straub and Mlecnik, 2014;). However, studies also show that successful retrofits are clearly associated with proactive house owners (Risholt and Berker 2013, Galvin and Sunikka-Blank, 2014).

For the SMEs contractors, who are often the main partner and consultant for this kind of operations (Risholt and Berker 2013, Vlasova and Gram-Hanssen 2014) the barriers are said to be the following: these contractors struggle to identify and invest in new business opportunities (Mokhlesian and Holmen 2012); they may lack technical knowledge and competences necessary to retrofit. There is limited customers' demands or market for it (Carlsson 2017). Tight time frames and lack of resources force them to apply standardized solutions (Archtnicht and Madelner, 2014). And even when the contractors have delivered an innovative solution, they usually go back to conventional practices when moving to the other projects (Killip 2013). More recent studies have focused on the interactions between the two customers and the contractors. Building on Albott's system of professions, Wade *et al.,* (2018) analyse how architects and heating installers may down-prioritize energy efficiency to the benefit of what they consider their main professional jurisdictions.

The present paper contributes to this stream of research focusing as well on the interactions between the house owner and the craftsman. However, the interactions observed are not related explicitly to retrofit solutions, our purpose is to study how the first negotiation between a craftsman and his or her potential client is taking place and if there is in this encounter, in the way the two parts are played and the shaping of expertise, elements which could account for the lack of retrofit. Building on Goffman dramaturgical theory, we focus on the routinised and taken for granted behaviours

which shape daily interactions (Goffman, 1959). According to the author, people interact according to their and their counter part's expectations in the specific context of a given situation and most conversation is simply a replaying of a strip (Goffman, 1961). Think for example how you order a beer in a bar and anticipate the waiter reaction.

Framework of Understanding

Goffman (1959) uses theatre and dramaturgy as metaphors to explain social life, interactions and situations. He argues that social life, just like a theatre, consists of persons performing roles on stage in front of an audience and that we exist through the meeting and interaction with others but also by being seen by others. Goffman focuses on micro-sociology, interactions and routinized behaviours and how interactions between actors, structures and artefacts enable actors to form and perform roles in specific settings. Accordingly, the expression a person gives involves communication in words, which the performer can control and non-verbal performances, the performer might have more problem to control (Goffman, 1959). Through interactions, individuals will partake in each other's performances and guide the performer's actions and the creation of his and their roles by their emotional expressions and actions (Goffman 1959). The performer is argued to present himself to the audience in a certain way, also according to the sociocultural and contextual rules and routines that are applicable for the specific situation, to establish a specific impression (Goffman, 1959; Schwalbe, 2013).

Impression management is an activity that takes place in interactions between actors either directly involved with one another (such as business meetings) or when the interaction is indirect (e.g. a buss full of strangers) (Koslowski and Pindeck, 2011). To create a positive impression with their audience a performer will use available scenery to his or her advantage. Scenery can, for example, be props, settings (physical and social), clothing and other artefacts as well as their own bodies in the form of bodily movements (Van Praet, 2009), to make their point to their audience. Actors adjust their roles and performances to different situations to create the impression they want to obtain (Goffman, 1959). This can for example be seen when a service provider meets a customer outside the ordinary service setting and adjusts the performance to create and sustain a desirable positive impression for the customer.

Props and settings also involve social symbolic meanings for actors to interpret and make use of. Dale (2005) shows how resources, as in for example materials, are suffused with power and prestige through their symbolism, which various actors then interpret differently. Thus, resources are understood as "combined material and social interaction" (Dale, 2005, p.651) where the interpreted social meaning of the symbols are stronger in influencing actors' performances and interaction processes. Lowe *et al.,* (2012) take the example of a business meeting and how it is not the number of seats that is important but how the seats are arranged to determine how the meeting will unfold. They further show how actors move in and out of settings and stages while changing roles and scripts. A setting impacts on an actor and an interaction and enables a certain range of activities and roles for the actors to engage in (Darr and Pinch, 2013). Van Praet (2009) suggests that the actors' body can be seen as the anchor of the performers' communicative skills, and to maintain a given definition of the situation. So, the performers show through used scenery, their body and performance what they want to express.

According to Lowe *et al.,* (2012) actors act differently in different settings and contexts depending on how they interpret the situation. Therefore, actions do not exist in a vacuum, but have to be seen and understood in the light of its history, its presence and future. The occurring actions are the link that connects the former experiences and the future wishes (Goffman, 1961). Individuals are also seen to improvise in their roles in relation to other people to find out what works and what does not work in the current context (Goffman, 1959). In a way the performers help and support each other to play their roles and make a good performance in the social play. Social roles are performed in relation to the "rules" the situation and the interaction demand (Preves and Stephenson, 2009). This means that social status, roles and interaction structures are created and developed through and during interactions (Schwalbe, 2013). However, actors do not just use the role they have for a certain setting but sometimes they distance themselves from the role to find another role or to show for other actors that they are aware of their own roleplaying (Pinch, 2010; Smith, 2013).

When discussing roles, it is important to highlight personal fronts. Clothes and bodily movements change the social rules and conditions for the performances (Van Praet, 2009). Each individual has a personal "front" consisting of social attributes, e.g. clothes, hair, gestures, body language, facial expressions, age, sex, etc. and tries through these personal artefacts to improve the impression given off (Goffman, 1959).

The personal front is argued by Goffman (1959) to be employed for two reasons: first to enable the performer to present himself as he likes to appear; and secondly because his appearance can improve his performance and make it more comprehensive.

The last concept we mobilise from Goffman's (1959) is "scripts". Scripts are considered to be situations in social life consisting of structured forms of actions which tend to repeat themselves in similar situations. Darr and Pinch (2013) for example studies several types of face-to-face encounters between service provider and customer to show how both use structured forms of actions and so produce and re-produce the social order of buying and selling. They argue that the performers in a service process often have distinct social roles which include well-defined scripts, like customer/buyer and service provider/seller.

The dramaturgical theory has been used in a variety of contexts, leadership studies (Gardner and Avolio, 1998); intra-organizational relationships (Murphy, 2009); organizational control (Dale, 2005); or accounting (Solomon *et al.,* 2013). In addition, there is only few studies addressing face-to-face sales' interactions (Darr and Pinch, 2013). Given the importance of technology driven changes in society, it is surprising that so few studies explore sales interactions of emergent technics, where actors negotiate what to buy, why specific solutions are chosen over others and what elements influence their choices. In construction management, very few have drawn on Goffman to the exception of Green (2006), who discusses how managers tasks performance is central to their shaping of their self-identities.

METHOD

We adopt an interpretivist understanding, using Goffman's dramaturgical theory (Goffman, 1961), to explore the interactions and analyse aspects of interactional expertise. The main concepts in focus in the research work were: performances and roles; social front; scripts (Darr and Pinch, 2013); front stage and back stage in role performances. The empirical material has been collected during the springs 2014 and 2015 via two main methods; observations and interviews.

Eight contractors participate in the round of observation of a total of 18 first interactions. One of the authors shadowed the 18 encounters between building professionals and single-house owners that had requested their services (Czarniawska, B., 2007). These observations took place in the houses to be renovated during the negotiation of the renovation scope, they lasted between 50 minutes and three hours. These meetings were generally organized by the building professionals after agreement with their customers.

Table 1: List of the people involved in the data collection

SMEs	Observ. house-own SME cont.	Compl. interview house-own.	Compl. interview SME
Electrician	1		1
Energy HAVAC 1	2	4	2
Energy HAVAC 2	3	2	3
Building contractor1	4	3	4
Building contractor 2	3	1	3
Construction and property service 1	2	3	2
Construction and property service 2	1		1
Insulation	2	3	2
Sum:	18	16	18

All interviews with the SME contractors were performed in their vans to, but mainly from, the house owner in question. 12 out of 18 house owners were interviewed after the observation at the house owners' homes, 10 straight after the performed observations when the contractors were busy doing things outside of the home owner house and two over the phone the same day. In addition, 4 follow-up interviews were conducted over phone two-three months after the observed event to get to know how things had gone and if they were satisfied with the contractors and the work they had performed. These interviews were informal without any prepared topics.

The observer played a secondary role during the observation, but she was acknowledged by all the participants. She was sharing the front and backstage of the craftsmen getting to hear and see information hidden to the potential customers. Her presence might have impacted the performances and the staging of the actors. A limitation to the shadowing is that the contractors might have felt the need to stage themselves for the researcher (for example as competent, experienced, skilled or trustworthy professional). Likewise, the house owners might have felt disadvantaged facing two visitors instead of one and unsecured for being observed which could have had implications on the house owners' actions and their staging (Schensul *et al.,* 1999). Finally, the observer is also acting according to specific scripts, such as visitor, university representative or young researcher (Carlsson and Koch, 2014).

In order to illustrate how expertise is performed and embodied during these interactions, we have selected one example among the observations. Though, this visit was a short one, it reveals several of the recurrent observed behaviours. The usage of a combination of methods enabled more nuanced insight into the contractors' performances in relation to energy renovations, also when interacting with house owners, and into how they express their role as a professional contractor. The paper

build on a PhD dissertation of the third author (Carlsson, 2017). She also carried out the fieldwork presented below.

Illustrative Case: House-Owner Craftsman Interaction

The SME contractor Niklas drives his pick-up truck with a relaxed hand. Coming to the house, he sighs loudly: "No, not one of those." He pulls the pick-up truck over and parks outside a house where the front yard is filled with junk, e.g. old rusty cars; plastic sheets; oil barrels; car pieces. We step out of the truck and he says with a voice probably just meant for himself: "I knew I shouldn't have gone here, just a waste of time." Niklas is dressed in jeans and a checked shirt, he takes a notebook and a folding ruler from the back of his truck and tells me: "Come on, let's get it over with". We head towards the grey painted wooden house which seems to barely be hanging together.

A man opens the front door, he has worn clothes. He smiles friendly, greets us, presents himself as Ove and shows us inside. I make a move towards my shoes, but he says that we should keep them on, I continue of politeness, but he insists. Ove then turns towards Niklas and immediately starts talking about how bad the kitchen is and how they now finally have decided that they need to do something about it. "Come in, come in" he says and walks ahead of us. We walk straight through the house to the kitchen which is at the backside.

All three of us cramp up in the end of the narrow and oblong kitchen. Ove explains: "We want to expand the kitchen by removing this wall…" He points at the wall where the refrigerator and freezer stand "to make the kitchen bigger so one can sit in it and eat and not have to walk around with the pots." Ove uses his whole body when he speaks. He waves his arms, point at things and when arguing for how narrow the kitchen is, he presses himself towards the cabinets and leans towards the countertop, to show how he has to do when he and his wife are there at the same time and want to pass each other. He suddenly turns around: "And then open up the wall here" and points at the outer wall, "and put in a door and have a porch on the outside." Niklas has taken out his notebook and writes in it. He looks where Ove points and make notes, lets him explain. Ove speaks again: "So, do you think it's possible? How long time will it take and when can you do it?" Ove turns, looks happy and leans eagerly towards Niklas, who looks up at him and says: "Humm" and continues to write notes. He then takes out his folding ruler, makes a comment that he should have brought his laser measurer and starts to measure. Niklas repeats the different things Ove just explained to us and notes it down with measurements. He moves so he can knock at the inside wall and ask Ove to have a look at it from the other side. "Of course," Ove says and shows us the other room, more things. Niklas leans over the things and tries to look at the wall. Ove says: "I find it difficult to throw things, but I figured that if the wall needs to go, I have to clean, at least in this room". He looks at me and smile, I smile back and nod. Niklas says: "Hmmm" again.

Ove walks up to the wall where he wants the door to be and claps on the wall. "Here should the door be" he says "and then a porch that are along the whole back of the house and like about this far out" … he walks in the grass and stands about 3-4 meters out from the house. "That's quite a big porch" Niklas comments. "What material do you think would be the best, we have thought about both wood and stone but we're not sure." Niklas says "Hmmm" and looks at the place for the porch. Once again, he folds out his folding ruler and starts to put down measurements in his notebook. While doing it Ove once again asks when Niklas can come and do the job.

Niklas says: "Hmmm" and I think he will go silent again but then he says, "Not before June at least, but after that it should be possible" (two months in the future). Niklas then makes a comment that wood would probably look better with the house, but he can give price suggestions with both alternatives.

When Niklas is done with the measurements he says that he needs to put it all down and make Ove and his wife a tender that he will send them over the mail. If they accept the tender, they can discuss more precise dates for when to conduct the work. Ove smiles and nods. He makes a comment that it is nice out now in the spring sun however a bit wet in the grass since last night's rain. We agree and smile. Niklas makes a comment that it will probably be warmer the week that is coming up, he then looks at his watch and says that we need to get going if we should make it till our next meeting. I know we do not have a next meeting, but I agree with him and we shake hands with Ove ...

When we both are in the truck with the doors closed Niklas expresses that this was one of the worst places he has seen when it comes to having a lot of junk. Niklas tells me that he will make a quick calculation, which will probably be a bit pricy and send it to them. "These people usually never have the money anyway so no use putting in too much effort into it".

This story could have ended right here, however three weeks after this meeting Niklas calls me to let me know that Ove had accepted the tender made to him. "Even though I deliberately made it overpriced" Niklas says. The job was performed (in late June) and Niklas got paid respective to the initial tendered made.

ANALYSIS

The first encounters between the craftsman and the customer is enabling both participants to decide if they want, or not as in the case above, to engage in the transaction. Niklas, discovering the plot assessed even before meeting the owner, that this visit is a waste of time and that Ove belongs to the category of "bad customers". This as well as the interior state of the house set the stage and conditioned his behaviour during most of the visit, where he appeared more reserved than in other interactions. The setting is crucial for the actor's interpretation and further actions relative to the material frame (Dale 2005). A contractor looks for clues and symbols with a house owner but also with a house owner's setting to get an idea about the upcoming job. In addition, the impression of any symbolic artefact, here the plot, the house, the clothes, can be seen to be transferred to the holder/owner of the artefact as part of the owner's front (Darr and Pinch, 2013).

Ove acts according to his role as a host, he smiles, tells the visitors they are welcome and shows them in etc. while doing so he demonstrates his owning of the setting and takes the lead of the interaction. His performance as host also implied that the contractor and the researcher are guests in his house, thus framing their performances. The guest role involved limitations for how to act to not walk freely in the house but keep with the host or in frontstage areas of the house (e.g. living room, dining room) or ask for permission if another place needs to be visited. Both visitors and guest act according to the expected script (Goffman, 1959).

Likewise, Niklas personifies his role as a craftsman, he wears the expected jeans and checked shirt, carries a ruler and a note book, drives a pick up bearing the name of his company. Building his personal front, these elements embody his identity as a professional builder and enable the use of impression management techniques and

their likelihood to influence his customers (Goffman, 1959). During the visit he goes around the rooms, knocks on walls, measures, takes notes, measures again, seems concentrated and focus on his task. He does not answer questions directly but mumbles to signify he has heard and keep the owner waiting. By checking the walls, he also controls the information given by the owner. These attitudes reinforce the impression of expertise and correspond to the expected performance of a qualified craftsman but also confine the owner in a passive role. The latter, having lived in the house for more than 30 years, feels very knowledgeable about it is expressed by his physical demonstration in the kitchen. However, Niklas is challenging this knowledge by adopting a scrutinising professional attitude, which creates doubt and uncertainties in Ove's mind. Though rather convinced that he does not want to take Ove's project, Niklas maintains his role as expert and conceals any hesitation or insecurity. He keeps his behaviour to the expected customer/ provider script (Darr and Pinch, 2013). There is no space to discuss alternative possibility or solutions. Both actors focus on the work to be done and don't provide space to other kind of topics during the interactions. The mentioning of the weather at the end of the encounters is marking the end of the exchanges.

CONCLUSIONS

The aim of this paper was to study how expertise is performed between house owners and SME craftsmen in a context of renovation and with a potential of energy renovation. Using Goffman's dramaturgical concept enable us to illustrate how the expertise is negotiated during the first encounter. We found that expertise is negotiated and interactively constituted through a public performance where the two actors demonstrate, contest, challenge and finally accept the role of expert. Expertise is therefore something shaped during the interaction, rather than a given attribute (see also Chan, 2016). The tensions (roles, performances), together with insecurities from both partners in interactions create challenges for innovation as the interaction with the established roles and performances can lock the two actors into a routinized play. The case described here is used as an example of the other cases studied highlights that in order to adapt to the concrete situation, perform their roles and answer each other expectations, the craftsman but also the owner don't find occasion to insert and develop alternative propositions. They are busy participating to the establishment of their own expertise and roles. There is no space to develop retrofit solutions if these have not been defined as one of the main purposes of the encounter. If the contractors were to promote energy retrofit, they would need to change their script radically and take the risk of jeopardising the ongoing encounter. So, to place SME contractors on the stage as responsible for the lack of energy renovations is to disregard the constraints of their professional role when they negotiate with their customers.

REFERENCES

Archtnicht, M and Madelner, R (2014) Factors influencing German house owners' preferences on energy retrofits, *Energy Policy*, 68, 254-263.

Barret, P and Sexton, M (2006) Innovation in small, project-based construction firms, *British Journal of Management*, 17(**4**), 331-346.

Carlsson, V (2017) *SME Contractors on the Stage for Energy Renovations? a Dramaturgical Perspective on SME Contractors' Roles and Interactions with House Owners*. PhD Thesis, Chalmers University of Technology, Sweden

Carlsson, V and Koch, C (2014) *Shall we dance? Encounters for energy renovation of single-family houses*. *In:* Raiden, A and Aboagye-Nimo, E (Eds.), *Proceedings 30th Annual ARCOM Conference*, 1-3 September 2014, Portsmouth, UK, Association of Researchers in Construction Management, 1163-71.

Czarniawska, B (2007) *Shadowing and Other Techniques for Doing Fieldwork in Modern Societies*. Malmö: Liber and Copenhagen Business School Press.

Chan, P W (2016) Expert knowledge in the making: Using a processual lens to examine expertise in construction, *Construction Management and Economics*, 34(**8**), 471-483.

Clark, T and Salaman, G (1998) Creating the 'right' impression: Towards a dramaturgy of management consultancy, *The Service Industries Journal*, 18(**1**) 18-38.

Dale, K (2005) Building a social materiality: Spatial and embodied politics in organizational control, *Organizatio*n, 12, 649-684.

Darr, A and Pinch, T (2013) Performing sales: Material scripts and the social organization of obligation, *Organization Studies*, 34(**11**) 1601-1621.

De Wilde, M, and Spaargaren, G (2019) Designing trust: how strategic intermediaries choreograph homeowners' low-carbon retrofit experience. *Building Research & Information*, 47(4), 362-374.

Freytag, P V and Storvang, P (2013) Facilitating innovations: Understanding the dynamics of actors' involvement in the construction industry *In*: *29th Industrial Marketing and Purchasing Conference 2013*, IMP Group, Atlanta USA.

Gardner, W L and Avolio, B J (1998) The charismatic relationship: A dramaturgical perspective, *Academy of Management Review*, 23, 32-58.

Galvin, R, and Sunikka-Blank, M. (2014) The UK homeowner-retrofitter as an innovator in a socio-technical system. *Energy Policy*, 74, 655-662.

Goffman, E (1959) *The Presentation of Self in Everyday Life*. London: Penguin Books Ltd.

Goffman, E (1961) *Encounters: Two Studies in the Sociology of Interaction*. Indianapolis: Bobbs-Merrill Co.

Green, S (2006) The management of projects in the construction industry: context, discourse and self-identity, *In*: D Hodgson and S Cicmil (Eds.) *Making Projects Critical*, Basingstoke: Palgrave Macmillan, 232-51.

Janda, K, Killip, G and Fawcett, T (2014) Reducing carbon from the 'middle-out': The role of builders in domestic refurbishment, *Buildings*, 4, 911-936.

Killip, G (2013) Products, practices and processes: Exploring the innovation potential for low-carbon housing refurbishment among small and medium-sized enterprises (SMEs) in the UK construction industry, *Energy Policy*, 62, 522-530.

Koslowski, M and Pindeck, S (2011) Impression management: Influencing perceptions of self, *In*: D Chadee (Eds.) *Theories in Social Psychology*, Oxford: Blackwell Publishing Ltd, 280-296.

Lowe, S, Purchase, S and Ellis, N (2012) The drama of interaction within business networks, *Industrial Marketing Management*, 41, 421-428.

Mahapatra, K, Gustavsson, L, Haavik, T, Aabrekk, S, Svendsen, S, Vanhoutteghem, L, Paiho, S and Ala-Juusela, M (2013) Business models for full-service energy renovation of single-family houses in Nordic countries, *Applied Energy*, 112, 1558-1565.

Mlecnik, E, Kondratenko, I and Haavik, T (2012) Business model development for customer-oriented housing renovation, *European Energy Innovation*, 28-29.

Mokhlesian, S and Holmén, M (2010) Business model changes in green construction: A literature review. *In:* Egbu, C (Ed.), *Proceedings 26th Annual ARCOM Conference*, 6-8 September 2010, Leeds, UK. Association of Researchers in Construction Management, Vol. 2, 997-1006.

Murphy, F (2009) Act, scene, agency: The drama of medical imaging, *Radiography*, 15, 34-39.

Nair, G, Mahapatra, K and Gustavsson, L (2010) Owner perception of the adaptation of building envelope energy efficiency measures in Swedish detached houses, *Applied Energy*, 87(**7**), 2411-2419.

Niskanen, J (2018) *Mainstreaming Passive Houses a Study of Energy Efficient Residential Houses in Sweden*. PhD Thesis, Linköping University, Linköping.

Pinch, T (2010) The invisible technologies of Goffman's sociology: From the merry-go-round to the internet, *Technology and Culture*, 51(**2**), 409-424.

Preves, S and Stephenson, D (2009) The classroom as a stage: Impression management in collaborative teaching, *Teaching Sociology*, 37(**3**), 245-256.

Risholt, B and Berker, T (2013) Success for energy efficient renovation of dwellings: Learning from private homeowners, *Energy Policy*, 61, 1022-1030.

Schensul, S L, Schensul, J J and LeCompte, M D (1999) *Essential Ethnographic Methods: Observations, Interviews and Questionnaires 2*, Lanham, MD: AltaMira Press

Schwalbe, M (2013) Situation and structure in the making of selves, *In*: C Edgley (Ed) *The Drama of Social Life: A Dramaturgical Handbook*. Farnham, UK: Ashgate Publishing Limited, 75-92.

Solomon J F, Solomon A, Joseph N L, Norton S D (2013) Impression management, myth creation and fabrication in private social and environmental reporting: Insights from Erving Goffman, *Accounting, Organizations and Society*, 38(**3**), 195-213.

Straub, A and Mlecnik, E (2014) Value propositions for business models for nZEB renovations, *In*: *World SB14 "Sustainable Building: Results" Barcelona Conference*, 28-30 October, Barcelona, Spain, 8-14.

Vlasova, L and Gram-Hanssen, K (2014) Incorporating inhabitants' everyday practices into domestic retrofits, *Building Research and Information*, 42:4, 512-524.

Van Praet E (2009) Staging a team performance: A ethnographic analysis of weekly meetings at a British embassy, *Journal of Business Communication*, 46 80-99.

Wade, F, Murtagh, N and Hitchings, R (2018) Managing professional jurisdiction and domestic energy use, *Building Research and Information*, 46(**1**), 42-53.

Williams, R, Faulkner, W and Fleck J (1998) *Exploring Expertise: Issues and Perspectives*. Houndmills: MacMillan.

IMPLEMENTING THE CIRCULAR ECONOMY IN BUILDINGS: PROCESSES OF SENSEMAKING IN DESIGN AND DELIVERY

Zoe Henderson[1], Beth Morgan[2] and Jeremy Watson[3]

[1&3] *Department of Science, Technology, Engineering and Public Policy (STEaPP), University College London, Euston House, 24 Eversholt Street, London, UK, NW1 1BS, UK*

[2] *The Bartlett School of Construction and Project Management, University College London, 1-19 Torrington Place, London, UK, WC1E 6BT, UK*

Resource consumption is inextricably linked to growing populations, economies and living standards, however this trend is fundamentally at odds with the finite nature of key resources and the fragile ecology on which the planet depends. The construction industry is a key economic sector, with a significant environmental impact, and as such it needs to develop and operationalise business models that reconcile some of the tensions that exist between economic and environmental prosperity. A promising approach to improving the productivity of resources lies in the principles of the Circular Economy, a closed loop model that keeps products and materials at their highest utility for as long as possible. However, there is limited understanding of how processes will need to change across the industry to accommodate this transition. This research focuses on the behavioural dimension of adopting Circular Economy models in buildings, which is based on the assumption that it is people, rather than technology, that are the key to embracing circularity. Findings are derived from qualitative case studies which are developed from semi-structured interviews in order to capture descriptive, in-depth and contextual knowledge. The preliminary results highlight two key phases for the successful implementation of circular solutions in buildings. The first centres on the process of initial decision making and project framing, whereby a clear, consistent vision of sustainable aspirations enabled narratives to be built around circular solutions. Secondly, the implementation of these solutions benefits from continual communication and consistent translation, linking corporate and sustainability targets to site performance. This suggests that the implementation of circular solutions is supported when parties align along strategic narratives, making the translation, demonstration and sharing of benefits derived from sustainability easier.

Keywords: circular economy, decision theory, design, sustainability

INTRODUCTION

The relationships between population growth, economic development and environmental conservation are complex, but in general, as economies expand so does the associated consumption of planetary resources (Jackson, 2009). During the twentieth century global consumption of raw materials rose at around twice the rate of population growth (OECD, 2018). However, these trends are fundamentally at odds with the crucially finite nature of these resources and the fragile ecology on which the

[1] zoe.henderson.16@ucl.ac.uk

Henderson, Z, Morgan, B and Watson, J (2019) Implementing the Circular Economy in Buildings: Processes of Sensemaking in Design and Delivery *In:* Gorse, C and Neilson, C J (Eds) *Proceedings of the 35th Annual ARCOM Conference,* 2-4 September 2019, Leeds, UK, Association of Researchers in Construction Management, 114-123.

planet depends for survival (Jackson, 2009). These tensions between growth, economic prosperity and environmental conservation are also reflected in the construction industry, which is one of the UK's primary economic sectors, accounting for 6% of the nation's Gross Domestic Product. However, the built environment is also a primary contributor to the UK's overall carbon footprint, accounting for nearly 8% of all primary energy and 24% of the UK's total waste (Stubbs, 2015). As such, the construction sector needs to develop and operationalise business models that reconcile some of the tensions between economic and environmental prosperity.

One promising approach to this problem is found in the Circular Economy model, which aims to prolong the productive life of resources. The Ellen MacArthur Foundation (2017) describes the Circular Economy as, "an industrial system that is restorative or regenerative by intention and design. It replaces the 'end-of-life' concept with restoration, shifts towards the use of renewable energy, eliminates the use of toxic chemicals, which impair reuse, and aims for the elimination of waste through the superior design of materials, products, systems, and, within this, business models" (The Ellen MacArthur Foundation, 2017). This circular model is built on reducing, reusing, recycling and recovering, with reducing seen as the highest priority and recovering as the final option (Kirchherr, Reike and Hekkert, 2017). The concept of a Circular Economy, and strategies for its implementation, are receiving increasing attention amongst practitioner communities, which Kirchherr, Reike and Hekkert (2017) argue is because it provides a model for businesses to effectively operationalise sustainable development (Kirchherr, Reike and Hekkert, 2017; Ghisellini, Cialani and Ulgiati, 2016).

This paper first reviews some of the barriers to adopting Circular Economy models in the built environment, with a particular focus on complexity and behavioural decision-making as part of a project's design and implementation. Empirical data is drawn from a case study on 1 Triton Square, developed through interviews with professionals engaged on the project. The findings that have emerged from this data suggest that circular designs were enabled through strategic alignment between project actors, initiated by the development of strong project narratives, and followed through into the construction phase with consistent processes of translation.

LITERATURE REVIEW

Pomponi and Moncaster (2017) note that current research on the Circular Economy tends to focus on either the macro-scale, such as cities and eco-parks, or the micro-scale, such as manufactured products. However, they argue that this focus ignores both the unique complexity and the significant potential of implementing Circular Economy in buildings (Pomponi and Moncaster, 2017). While buildings are constructed from a multitude of manufactured products and materials, when combined, the dynamics of the design and construction process do not necessarily fit conventional models of manufacturing. Instead, buildings may be more comparable to Complex Products and Systems (CoPS) (Gann and Salter, 2000), which are defined as high cost, highly customised, engineering-intensive products or services that require a degree of knowledge production (Hobday, 1998). CoPS are typically delivered within projects, and as such resources and technical expertise are rarely managed or mobilised within a single firm (Gann and Salter, 2000). Since projects are typically delivered in collaboration with other firms "almost all innovations in construction have to be negotiated with one or more actors within the project coalition" (Winch, 1998). Therefore, as part of construction processes, it is the

interactions between players in the market that becomes crucial to the implementation of new ideas and models (Edquist, 2011). Pomponi and Moncaster (2017) argue that this behavioural dimension to adopting Circular Economy models in buildings is seldom featured in the literature (Pomponi and Moncaster, 2017). However, they also argue that there is a strong case for accelerating this, claiming that "it is people, rather than technologies, who are the key to embracing circularity" (Pomponi and Moncaster, 2017). This idea is particularly true of the initial decision-making process of a project, where uncertainty is at its highest and it is where some of the most influential 'project shaping' choices occur (Miller and Lessard, 2008).

The importance of the front-end decision-making phase in construction projects is being increasingly recognised, with key themes including the alignment of project and organisational strategies, dealing with complexity, accounting for biases in the estimation of benefits and costs; as well as the social geography and politics that exist within decision-making groups (Williams and Samset, 2010). Apply a behavioural decision making lens, Flyvbjerg (2005) argues that one of the primary problems with infrastructure projects is misinformation about costs, benefits, and risk, which he believes is caused by deliberate misrepresentation in order to increase a project's chances of being approved and ultimately funded (Flyvbjerg, 2005). This view of behavioural decision-making in projects assumes that decision-makers can be influenced by political interests, which allows for the introduction of opportunistic behaviour and conflict of interests (Stingl and Geraldi, 2017).

However, another view of the behavioural aspects of decision-making in projects assumes that "decision makers do not 'make' decisions, but are actors constructing narratives which will shape processes of attention, prioritisation and ultimately decisions", as such decisions are processes of sensemaking that are intertwined in the negotiation of meaning before, during and even after a project (Stingl and Geraldi, 2017). Applying a sensemaking lens focuses on the interplay of interpretation and resulting actions, as opposed to the influence of evaluation on choice (Weick, Sutcliffe and Obstfeld, 2005). Communication is a central component of sensemaking and as such, translation, negotiation and the development of common narratives are key. For example, Sorrell (2003) notes that while one party may have all the relevant information on the costs and benefits of an energy efficiency investment, it may be difficult to convey this to others (Sorrell, 2003). Similarly, project specifications will, consciously or not, be written from the perspective of one stakeholder, and as such will be subject to variable interpretations through each actor's different frames of reference and processes of sense-making (Alderman and Ivory, 2011).

METHODOLOGY

Considering cases where elements of circular design have been successfully implemented in the built environment, this research's methodology is chosen in order to effectively answer the question, how do design and decision-making processes contribute to the successful implementation of circularity? Since these research questions are descriptive in nature, this research employs a qualitative methodology in order to capture equally descriptive, in-depth and contextual knowledge. This takes the form of a series of comparative case studies, which provide an in-depth investigation of a contemporary phenomenon (Yin, 2018). This aims to develop an understanding of the causal relationships and mechanisms that exist within what is a complex social system. Comparative case studies enable the observation of patterns regarding similarities and differences across a moderate number of cases, and

therefore combine depth with a more extensive approach (Bergene, 2007). Studying common phenomenon across contexts is not a basis for prediction but to explore the existence and activation of a mechanism within different settings setting (Williams and Wynn, 2012).

Each case study is set within Arup, a multidisciplinary consulting firm specialising in the built environment, with cases selected primarily on account of the fact that each of the projects they describe have successfully implemented elements of circularity. Case studies are also bounded temporarily, ensuring that the research investigates relatively contemporary phenomenon. As such, each of the case studies chosen will have been active within the last 5 years. The emerging results from 1 Triton Square will be presented in this paper, while case studies of Sky Believe in Better Building and White-Collar Factory will be presented in future papers.

Project	Characteristics	Element of Circularity
1 Triton Square	Commercial property; London, UK; Refurbishment; Under construction	Refurbishment; Retention of existing structure and fabric; Health and wellbeing; Social focus
Sky Believe in Better Building	Commercial property; London, UK; New Build; Completed	Flexibility; Adaptability; Health and wellbeing; Social focus
White Collar Factory	Commercial property; London, UK; Redevelopment; Completed	Flexibility; Adaptability; Long life, loose fit; Easy to maintain; Health and wellbeing;

Basing each case study in a single organisation will, to some extent, control for the effects of organisational structure, business strategy and overarching design philosophy. Adopting a holistic, multi-case design will also account for the fact that contextual conditions and exogenous influences will vary across teams and individual projects. As such, it is important that each project case study receives equal empirical treatment and are analysed within their own project specific contexts. However, it is assumed that these case studies exist within open systems which are complex and have dynamic, permeable boundaries that are beyond a researcher's ability to control. As such, it is assumed that this reality is hard to capture, and that we, often subjectively, experience only parts of it. Therefore, in order to holistically study these complex organisational phenomena, this research adopts a critical realist research paradigm (Bhaskar, 1975).

Data Collection

For the 1 Triton Square Case Study, data has been collected from multiple sources, including a non-exhaustive list of project practitioners, as well as associated internal documentation. This method enables the gathering of rich, descriptive data, which is collected within its real-world context and directly from the actors who have experienced the events being studied (Brinkmann, 2014).

Source	Affiliation	Type	Length
Project Director	Client	Interview	1 hour
Sustainability Manager	Client	Interview	1 hour
Sustainability Manager	Contractor	Interview	1 hour
Sustainability Consultant	Designer	Interview	1 hour
Project Leader	Designer	Interview	30 min
Sustainability Brief for Developments	Client	Document	33 pages
Project Tracker: Implementation of the 2015 Sustainability Brief for Developments	Client/Designer	Document	31 pages

The interview protocol adopts a semi-structured approach, which is designed to ensure that lines of enquiry are thorough and remain focused on the overarching research questions, while remaining open to potential avenues of questioning and avoiding those that are overly leading (Glaser and Strauss, 1967). Data gathering also occurs in parallel to the initial stages of analysis enabling the research to cycle between "emergent data, themes, concepts, and dimensions and the relevant literature" (Gioia, Corley and Hamilton, 2012). As such, the interview protocol recognises that the interview questions may change as the research progresses in order to follow wherever the informants lead the investigation of the overarching research question, "following the twists, turns, and roller-coaster rides involved in discovering grounded theory" (Glaser and Strauss,1967).

Data Analysis

The data from these interviews has been coded thematically, first 'in-vivo' by remaining faithful to the informant's own language (King, 2012) and then by grouping these informant-centric terms and codes into categories based on more conceptual and theoretical terms (Gioia, Corley and Hamilton, 2012)

PRELIMINARY RESULTS

This paper presents results which have begun to emerge from the case study on 1 Triton Square, a significant redevelopment project in London's West End, providing environmentally responsible and socially active modern office space as well as improved public facilities. Key to the project's circular credentials is the retention of the existing structure and building facade, as well as the maximisation of wellbeing through exceptional amenities, daylight and social connectivity.

Emergence

A number of informants spoke about the early stages of the project as a process of exploration, with one noting that "there shouldn't be a ready-made template, because each job deserves that time of just letting it turn into something of its own accord". In the case of 1 Triton Square this process of emergence was described as being, in part, guided by "finding that special thing about that place, that location, what we're going to do there, and how that ties in everyone else", "it's the mindfulness of being in a nice place. You can't touch it, you can't measure it, but you know when you're there. You can clearly see that in different places." The intangibility of these aspirations were framed by the client British Land's almost conflicting priorities, with one informant noting that "they want to be […] one of the landlords with the top end properties, but they […] also want to feel like they're close to the ground […] so their aspirations are on the whole […] about creating, bridging that gap between the business side and making profit […] and the people on the ground who they're not necessarily leasing the space to but it's [about] making sure that it feels open and united". However, it was noted that developing these aspirations into a physical scheme required extensive negotiation in order to translate this into a tangible design.

In terms of beginning to draw out and shape this vision British Land were guided by their overarching strategy, which is to deliver sustainable long-term value by creating 'Places People Prefer'. This includes developing attractive and engaging real estate through placemaking that promotes health, productivity and enjoyment. As well as a commitment to making a positive contribution locally through the promotion of social inclusion, interaction and accessibility. Bringing together the vision and the strategy, British Land were able to converge around a number of aspirational social, economic

and environmental trends by aligning their corporate and sustainability strategies around four focus areas. These include skills and opportunities, wellbeing, community and futureproofing. British Land used these four areas to successfully and strongly link their sustainability and corporate strategies, recognising that the value derived from sustainability, wellbeing and place making also have a positive impact on driving financial value, with one informant noting that "sustainability is very much part of what we do, and it is very much part of our business model, it has to sit with that", "otherwise as a business we would not succeed." Beginning the project with a lack of preconceptions enabled the emergence of ideas based around value-based outcomes, as opposed to technical outputs.

Adopting this approach meant that, as one informant put it, "you're not always faced [with the fact] that demolition and rebuild is the only model in town", with another noting that the translation of the vision and aspiration into a tangible design was "where the legacy piece comes into place for reuse and for respecting the space as it is and then seeing […] what else does that mean […] in terms of what's there". In terms of pushing the sustainability of a scheme this openness and clarity of vision allowed designers to demonstrate the strategic alignment of more sustainable, and in particular, circular solutions. For example, in addition to thorough investigation, calculations and data, informants noted the importance of creating narratives that were in line with the client's language and values in order to inform and persuade. In doing so, designers were able to turn the retention of the facade "into a good story in terms of legacy for the client", appealing to both their sustainability and corporate strategies, citing the market value increase and differential market positioning, as well as the significant reductions to carbon.

Delivery

However, an important aspect of implementing these sustainable and circular interventions is ensuring that they are followed through on, since there is a risk that solutions are lost as the project progresses. For example, informants noted that "we do know that sometimes further down the line, unless they are absolutely embedded in the spec there's likely to be some push back when the cost comes into play and value engineering starts to take over." In order to counteract this, the sustainability brief was designed to support this follow through by assigning clear lines of responsibility and accountability as part of the design team set up. Additionally, it was noted by informants that this responsibility didn't "just land on a sustainability person, who's sat in a corner somewhere and struggling to be heard. It is actually owned by every member of the team, and they're aware of it from the offset."

Another informant agreed, arguing that "having that clarity in terms of exactly what needs to be done by whom is essential." In the case of 1 Triton Square, fostering this sense of ownership has been dependent on a number of factors. Firstly, it began with the client, with informants noting that you "start from your top level stakeholders", and that "once you've secured that pitch and you have a really clear target, [it] makes it easier to translate that corporate target into something tangible for your design team and site team." This was then furthered by a process of continual communication and consistent translation, constantly "linking the corporate world […] to site performance and appreciating that those languages are very different". For example, a goal of reducing embodied carbon in construction by 15% is a relatively abstract target, and while, as one informant put it " some people know what a tonne of carbon is […] unless you are quite clear, I mean this much materials, I mean these are the things we

want you to do in terms of […] passive design or, this is what we mean and it's in a spec, but we want you to make sure you do something else on site to push it. So, unless you've translated it then it's a no-go."

However, there are a number of barriers that hinder this process of translation. In particular, the psychological barriers associated with asking people to re-evaluate and change their everyday practices, with one informant noting that "it can often feel personal to them. They've done things a certain way for years, they pride themselves on work they're doing". As such, the skill in translating the benefits of sustainable interventions and creating shared understanding of intermediaries among actors, comes not just from having knowledge and data, but from being able digesting that information and communicate it in language that a site person will be able to relate to. For example, it was noted that when the design team "talked to the contractor [they] talked to them about why would it be good for them, [and] how it can reflect well on them to […] implement this tougher methodology and change their practice." Practically, this meant upskilling the workforce through consistent toolbox talks, with informants noting that "it goes from the top level all the way to the bottom level, and it's [about] having this meaningful unifying culture and to make sure that it is filtered through and communicated all the way down that enables us to perform, ultimately to perform better."

DISCUSSION

As discussed, one of the primary barriers to implementing more sustainable solutions in the built environment has historically been the organisation of the construction industry itself, and in particular, the asymmetry of information and incentives between parties. For example, Sorrell (2003) notes that while one party may have all the relevant information on the costs and benefits of an energy efficiency investment, it may be difficult to convey this to others, arguing that enabling frictionless sharing of information would allow for more the more equitable distribution of benefits (Sorrell, 2003). Emerging from this research to date is a focus on processes of convergence and translation as well as the interplay of social geographies that exist within decision-making groups (Williams and Samset, 2010). Notably summarised by one informant, "it's about linking the corporate world […] to site performance and appreciating that those languages are very different […]. Often that is the performance gap that we see between […] what the aspiration is, and what the end product is." The preliminary results highlight two key phases for linking corporate and site performance in order to successfully implement circular solutions in buildings.

Project Framing

The first centres on the process of initial decision making and project framing. Here Weick, Sutcliffe and Obstfeld (2005) argue that the process of "sensemaking starts with chaos" and the organisation of flux (Weick, Sutcliffe and Obstfeld, 2005). Beginning the project with a period of flux and a lack of preconceptions enabled the emergence of ideas based around value-based outcomes, as opposed to technical outputs. As such, a clear, consistent vision of sustainable aspirations enabled narratives to be built around circular solutions. In addition to thorough investigation, calculations and data, parties were able to utilise narratives that were aligned strategically, as well as to each other's language and values in order to inform and persuade. For example, designers were able to turn the retention of the facade "into a good story in terms of legacy for the client", appealing to both their sustainability and corporate strategies, citing the market value increase and differential market

positioning, as well as the significant reductions is carbon and material impacts. As such, the implementation of circularity and the associated decision-making processes were dependent both on evaluation, through thorough investigation, calculations and data, as well as what Weick, Sutcliffe and Obstfeld (2005) describe as the interplay of interpretation and resulting actions, which included the translation and negotiation of design (Weick, Sutcliffe and Obstfeld, 2005).

Translation

Secondly, the implementation of these solutions benefited from continual communication and consistent translation, linking corporate and sustainability targets to site performance. Communication is a central component of sensemaking and as such, translation, negotiation and the development of common narratives are key. In this case the skill in translating the benefits of sustainable interventions and creating shared understanding of intermediaries among actors, came not just from having knowledge and data, but from being able digesting that information and communicate it in language that a site person will be able to relate to. This empathetic approach to translating and communicating benefits was particularly important in overcoming some of the psychological barriers associated with asking people to re-evaluate and change their everyday practices. When combined, the strong project narrative, as well as the empathetic translation created a meaningful unifying culture, suggesting that the implementation of circular solutions is supported when parties align along strategic narratives, making it easier to translate, demonstrate and share the benefits of sustainability.

CONCLUSIONS

The preliminary results from this research have highlighted two key phases for the successful implementation of circular and sustainable solutions in buildings. The first centres on the process of initial decision making and project framing. In the case of 1 Triton Square, a clear, consistent vision of sustainable aspirations enabled narratives to be built around circular solutions. For example, the retention of the facade provided a "good story in terms of legacy for the client", appealing to both their sustainability and corporate strategies, citing the market value increase and differential market positioning, as well as the significant reductions in carbon and material impacts. Secondly, the implementation of these circular solutions, have to date, benefited from consistent follow through, including clear lines of responsibility and accountability, as well as processes of translation, which creates a unifying culture that ensures sustainability targets are filtered through and communicated to those on-site.

While split incentives are often cited as a primary barrier to achieving sustainability in the built environment, it is understandable that differing priorities exist between parties acting with a project coalition. However, these preliminary results suggest that instead of attempting to align incentives, there is a benefit in parties aligning along strategic narratives, making the translation, demonstration and sharing of the benefits from sustainability easier. This supports previous work by Alderman and Ivory (2011), which theorises that translations are more efficient in convergent projects where "understanding of intermediaries among actors is shared" (Alderman and Ivory, 2011). This work contributes to literature on behavioural decision-making in Complex Products and Systems (CoPS), with a focus on this in the context of applying Circular Economy models in the built environment. Applying a behavioural decision-making lens to the implementation of circularity suggests that decision-

making processes may need to be cognisant of both technical evaluation, through thorough investigation, calculations and data, as well as what Weick, Sutcliffe and Obstfeld (2005) describe as the interplay of interpretation and resulting actions, which included processes of translation and negotiation (Weick, Sutcliffe and Obstfeld, 2005).

REFERENCES

Alderman, N and Ivory, C (2011) Translation and convergence in projects: An organizational perspective on project success, *Project Management Journal*, 42(**5**), 17-30.

Arup (2016) *The Circular Economy in the Built Environment*. London: Arup Available from https://www.arup.com/perspectives/publications/research/section/circular-economy-in-the-built-environment [Accessed 05/12/2018].

Bergene, A (2007) Towards a critical realist comparative methodology: Context-sensitive theoretical comparison, *Journal of Critical Realism*, 6(**1**), 5-27.

Bhaskar, R (1975) *A Realist Theory of Science*. Hassocks, England: Harvester Press.

Brinkmann, S (2014) Interview *In:* T Teo (Ed.) *Encyclopaedia of Critical Psychology*. New York, NY: Springer.

Edquist, C (2011 Design of innovation policy through diagnostic analysis: Identification of systemic problems (or failures), *Industrial and Corporate Change*, 20(**6**), 1725-1753.

Ellen MacArthur Foundation (2017) *What is a Circular Economy*? Ellen MacArthur Foundation, Available from https://www.ellenmacarthurfoundation.org/circular-economy/concept [Accessed 7 Jan 2019].

Fleetwood, S (2004) The ontology of organisation and management studies, *In:* S Ackroyd and S Fleetwood (Ed.) *Realist Applications in Organisation and Management Studies 1st Edition*. London: Routledge.

Flyvbjerg, B (2005) Policy and planning for large infrastructure projects: Problems, causes, cures, *SSRN Electronic Journal*.

Gann, D and Salter, A (2000) Innovation in project-based, service-enhanced firms: The construction of complex products and systems, *Research Policy*, 29(**7-8**), 955-972.

Ghisellini, P, Cialani, C and Ulgiati, S (2016) A review on circular economy: The expected transition to a balanced interplay of environmental and economic systems, *Journal of Cleaner Production*, 114, 11-32.

Gioia, D, Corley, K and Hamilton, A (2012) Seeking qualitative rigor in inductive research, *Organizational Research Methods*, 16(**1**), 15-31.

Glaser, B and Strauss, A (1967) *Discovery of Grounded Theory: Strategies for Qualitative Research*. London: Taylor Francis Group.

Hobday, M (1998) Product complexity, innovation and industrial organisation, *Research Policy*, 26(**6**), 689-710.

Jackson, T (2009) *Prosperity Without Growth? the Transition to a Sustainable Economy*. London: Sustainable Development Commission. Available from http://www.sd-commission.org.uk/data/files/publications/prosperity_without_growth_report.pdf [Accessed 15 Mar 2019].

King, A (2012) In Vivo Coding *In:* L Given (Ed.) *The SAGE Encyclopaedia of Qualitative Research Methods*. Thousand Oaks: SAGE Publications, Inc, 473-474.

Kirchherr, J, Reike, D and Hekkert, M (2017) Conceptualizing the circular economy: An analysis of 114 definitions, *SSRN Electronic Journal*, 127(2017).

McDonough, W and Braungart, M (2008) Remaking the way we make things: Creating a new definition of quality with cradle-to-cradle design *In:* D Marinova, D Annandale and J Phillimore (Ed.) *The International Handbook on Environmental Technology Management*. Cheltenham: Edward Elgar Publishing.

Miller, R and Lessard, D (2008) Evolving Strategy: Risk Management and the Shaping of Mega-Projects *In:* H Priemus, B Flyvbjerg and B van Wee (Ed.) *Decision-Making on Mega-Projects: Cost-Benefit Analysis, Planning and Innovation*. Cheltenham: Edward Elgar Publishing.

OECD (2018) *RE-CIRCLE: Resource Efficiency and Circular Economy Project*, OECD Available from https://www.oecd.org/environment/indicators-modelling-outlooks/brochure-recircle-resource-efficiency-and-circular-economy.pdf [Accessed 30 Nov 2018].

Pomponi, F and Moncaster, A (2017) Circular economy for the built environment: A research framework, *Journal of Cleaner Production*, 143, 710-718.

Sorrell, S (2003) Making the link: Climate policy and the reform of the UK construction industry, *Energy Policy*, 31(**9**), 865-878.

Stingl, V and Geraldi, J (2017) Errors, lies and misunderstandings: Systematic review on behavioural decision making in projects, *International Journal of Project Management*, 35(**2**), 121-135.

Stubbs, B (2015) *Plain English Guide to Sustainable Construction*, Constructing Excellence, Available from http://constructingexcellence.org.uk/wp-content/uploads/2015/02/SUSTAINGUIDE.pdf [Accessed 26 Nov 2015].

Weick, K, Sutcliffe, K and Obstfeld, D (2005) Organizing and the Process of Sensemaking, *Organization Science*, 16(**4**), 409-421.

Williams, C and Wynn, D (2012) Principles for Conducting Critical Realist Case Study Research in Information Systems, *Mis Quarterly*, 3(**36**), 787-810.

Williams, T and Samset, K (2010) Issues in front-end decision making on projects, *Project Management Journal*, 41(**2**), 38-49.

Winch, G (1998) Zephyrs of creative destruction: Understanding the management of innovation in construction, *Building Research and Information*, 26(**5**), 268-279.

World Green Building Council (2014) *Health, Wellbeing and Productivity in Offices: the Next Chapter for Green Building*, World Green Building Council. Available from https://www.worldgbc.org/sites/default/files/compressed_WorldGBC_Health_Wellbeing__Productivity_Full_Report_Dbl_Med_Res_Feb_2015.pdf [Accessed 15 Mar 2019].

Yin, R (2018) *Case Study Research and Applications: Design and Methods 6th Edition*. Los Angeles, CA: SAGE.

CONSTRUCTION IS A HIGHLY PRODUCTIVE INDUSTRY

RELATIONSHIP BETWEEN LABOUR PRODUCTIVITY AND CURVED WALL CONSTRUCTION IN HIGH-RISE BUILDING PROJECTS

Rex Ugulu[1], Andrew Arewa[2] and Allen Stephen[3]

[1] *Quantity Surveying Department, Federal University of Technology, Owerri, PMB 1526, Nigeria*

[2] *Quantity Surveying and Commercial Management, Coventry University, Priory Street, Coventry, CV1 5FB, UK*

[3] *School of Built Environment, University of Salford, The Crescent, Salford, M5 4WT, UK*

Construction labour productivity has been declining. This paper examines the learning effect of labour productivity in a curved wall operation using the application of the Learning Curve Theory (LCT). The research adopted a quantitative approach, utilising a standard observation sheet to record labour productive time on a live project. The study investigated a 15-storey office building project in Nigeria. Data were analysed using regression analysis and straight-line learning model. The result of the effect of learning on curved wall operations shows a significant influence on improvement in labour productivity. The labour productivity observed reveals average learning rate of 93.76%, resulting in an improvement rate of 6.24% in labour productivity. This impact can decrease the duration of the project at a rate of 1% - 6%. A learning rate of less than 100% indicates that learning has occurred and is verified by the LCT. The research contributes to development of a model for investigating labour productivity curved wall operations with the application of LCT. The model developed in this research can help the construction industry, project managers and planners to view the rate of labour productivity in a learning curve diagram. This study was limited to a single site multi-storey building due to the deductive method of the research. The implication is that the study result may lack generalisability. It is suggested that this investigation is replicated with other models, i.e. piecewise unit model, exponential model and cubic unit model of learning.

Keywords: curved-walls, learning-curve-model, operations, measurement

INTRODUCTION

For decades, the construction industry has been afflicted by productivity growth. One explanation is nature of construction operation vis-a-vis workforce influences on global average value-added per hour. Productivity issues are particularly dismal in rich countries. For example, France, Italy, German and Japan has seen productivity growth fallen by about a sixth (Office National Statistics (2019). Arguably, construction productivity growth is worst in developing countries such as Nigerian, India and Brazil. Indeed, construction of curved walls has a remarkable influence on labour productivity and is often most noticeable characteristic in buildings (Granadeiro *et al.,* 2012). Curved wall construction is a component of modern forms of architecture that significantly influences construction labour productivity (Mashina

[1] rexugulu@gmail.com

Ugulu, R, Arewa, A and Stephen, A (2019) Relationship Between Labour Productivity and Curved Wall Construction in High-Rise Building Projects *In:* Gorse, C and Neilson, C J (Eds) *Proceedings of the 35th Annual ARCOM Conference,* 2-4 September 2019, Leeds, UK, Association of Researchers in Construction Management, 125-133.

and Gadi, 2010). Ourghi *et al.,* (2007) developed a tool to predict the influence of curved walls productivity on limited shapes and found that curved wall influences construction labour productivity significantly. However, there is rare study about learning effect of labour productivity in a curved wall operation using Learning Curve Theory (LCT).

The significance of labour in construction productivity cannot be overemphasized; particularly as it relates to project completion within cost and time targeted. The construction industry, particularly contractors usually consider productivity of labour rates as a fundamental factor of project success (Missbauer and Hauber, 2006). Construction labour productivity has witnessed a downward turn in the last two decades (Durdyev and Mbachu, 2018, Naoum, 2016). Perhaps, this is exacerbated by deteriorating relationship between different labour unions and other associations within construction supply chain. Moreover, labour productivity is regularly considered as slow to responding to clients' evolving requests. Various studies opine that contractual worker's practices need to change from engendering obsolete techniques to quick information assimilation from both external and internal environments for progressive, gainful and productive techniques (Rao *et al.,* 2015, Kululanga *et al.,* 2002). The merits of incorporating the Learning Curve Theory (LCT) as a feature of everyday contractual workers' schedule was recently addressed in some investigations (Thomas *et al.,* 1986, Couto and Teixeira, 2005, Jarkas, 2010, Ugulu and Allen, 2018).

LCT supposition is that labour productivity can be enhanced by performing a task repetitively (Thomas *et al.,* 1986). LCT states that whenever production quantity of an item doubles, the cumulative average cost or labour hours decreases by a level of percentage of total average rate or first unit rate. This percentage is depicted as the learning rate (Couto and Teixeira, 2005). However, other researchers advocated positive learning effect of labour productivity (Jarkas, 2010, Couto and Teixeira, 2005). Thomas (2009) stated that a talented labourer can profit on the lessons gained from experience. Everett and Farghal (1997) expanded the work of Thomas *et al.,* (1986) and found that labour productivity could be improved if workers can gain from previous experience. A phenomenon regularly portrayed as an effect of learning. Franco *et al.,* (2004) uncovered that improved performance in construction projects is synonymous with labour learning from performance feedback perspective. Wong *et al.,* (2012) assert that impact of labour performance is dependent on construction organizations' training and commitment to learning.

A significant number of investigations carried out utilised the use of surveys and practitioners perceptive based on literature reviews. Generically, there seems to be a general understanding among researchers that change in performance of labour is not incidental (Jarkas, 2015, Mohamed *et al.,* 2019). To a certain extent, it can be as a result of a subtle learning process, though little consideration has been paid to addressing what exactly workers learn (Jarkas, 2010, Ugulu and Allen, 2018). Nevertheless, such a recommendation has yet been supported by enough scientific evidence (Jarkas and Horner, 2011). Besides, it is justifiable that there are a variety of ways by which productivity improvement can be accomplished (Greve and Audia, 2006). For instance, the performance of labour might be improved by the learning experience gained during construction, the capability of management of the project manager, as well as the capacity to control project monitoring outcomes (Everett and Farghal, 1997, Love and Josephson, 2004).

The aim of this paper is to examine how learning affects labour productivity during curved wall operations in high-rise construction. Study of curved wall operations and the learning effects with the application of the LCT on repetitive operations would be of great benefit to construction managers and the construction industry.

LITERATURE REVIEW

Labour Productivity in Construction

Productivity is the relationship between work hours used to produce output and production. It is also the relationship between the output and input factors used to produce the output by a system. This description is derived from earlier definitions on productivity (Ugulu and Allen, 2018, Thomas and Zavrski, 1999, Tran and Tookey, 2011). Productivity rates are an essential aspect to be considered in the construction industry because they are output efficiency indicators of the sector (Mohamed *et al.,* 2019). According to Mohamed *et al.,* (2019) the 'project type' is the most important factor that influences productivity of labour in rebar construction.

Durdyev and Mbachu (2018) investigated factors influencing the productivity of construction labour in residential projects. These factors were grouped into four main groups: workforce, resource, management and external. The study found that the main factors affecting labour productivity are leadership, change order management, defective work and flow of cash. In South Africa, studies found that "late drawing, issue of specifications, delay, illegal strike action and lack of motivation as major factors that influences productivity" (Bierman *et al.,* 2016, Ugulu and Allen, 2017).

Ugulu and Allen (2018) investigated the influence of craft gangs onsite learning productivity using observation method and found a significant impact of learning on craft gangs' productivity. Learning curve theory relies on a crucial human nature, and capability to gain from past understanding, the strategy begins from individuals or groups repeating a comparative task and gaining experience from their association or practice. Long *et al.,* (2013) "examine the relationship between building floor and labour productivity of the structural work including formwork installation and rebar fabrication/installation," utilising the LCT. The study found 86.9% significant improvement. In a similar study, Jarkas (2010) investigated the "effects and relative influence of grid patterns; variability of foundation sizes; total surface area; and average surface area, on formwork labour productivity of isolated foundations". The study found strong correlation and high determination coefficients between labour productivity and the factors investigated i.e. 90.40 and 92,90 per cent. The rule of the LCT, which has been used reasonably in manufacturing, can moreover be used in building and construction industry (Thomas *et al.,* 1986).

Apparently, different learning curve models are used for improving labour productivity with repetitive activities in the construction industry exist, but learning curve mathematical models commonly used are: straight line unit model, Stanford unit '8' model, cubic unit power model, piecewise unit model and exponential unit model (Thomas *et al.,* 1986). The investigation carried out by Thomas *et al.,* (1986) utilised the output and construction production data gathered from 65 construction labour activities to examine the best evaluating model between the cubic and exponential and straight-line models. The straight-line model has the advantage of straightforwardness. However, it may not be reliable since the learning rate is expected to be consistent. The cubic unit model of learning always brought about a

higher coefficient of determination and was the reasonable model for displaying the impact of earlier learning developed (Thomas *et al.,* 1986).

The piecewise unit model involves three different stages, each of the stages with a learning percentage, the exponential model was founded on the hypothesis that portion of cycle per time is permanent and subject to improvement through repetition of the same task (Norwegian Building Research Institute, 1960). Previous investigation revealed that the cubic and piecewise learning curve model has a better coefficient of determination compared to the straight-line learning model (Duff *et al.,* 1987). However, these researchers observed that either the piecewise or the cubic model of learning curve provides a reasonable benefit regarding phenomenon of learning for the generalization of labour productivity in the construction project.

Straight-line learning model techniques was introduced to overcome such drawbacks and has comparative advantages compared to others because it helps project managers and planners to view rate of labour productivity learning in a LCT diagram (Thomas *et al.,* 1986). The LCT diagram enables the user to easily get all the needed information. It identifies relationship easily between activities, represent the different production rates between productivity rates of activities, and are regarded as an easier way for determining progress rates and estimating the present crew's construction performance. It is evident from the study literature that construction activities have been applying learning curve theory to their activities due to repetitive features and labour intensive. The study examined curved wall operation in a high-rise building project and used straight-line learning curve model to understand its effect on labour productivity

METHODOLOGY

This research adopted a quantitative approach. According to Leedy and Ormrod (2013) quantitative research includes the utilization of logical inquiry that embraces a speculative deductive method that deals with testing theories. This method considers huge indicators of credibility, for example, reliability, validity, generalizability, and reproducibility. Quantitative research is typically considered as an objective positivist endeavour with little depth (O'leary, 2010).

This research utilised a standard observation sheet as the research instrument to record the labour productivity input and output as supported by earlier researchers (Jarkas, 2010, Couto and Teixeira, 2005). The design of the observation sheet includes the following important features: observed time, weather condition, wall thickness, crew composition, wall type, height worked and method of work. The description of the observed project was a 15-storey office building in Abuja, Nigeria. The project office complex has a gross area of about 81,000 sqm comprising 445 car parking spaces. The focus on the project was on curved walls which have common features as stated in the design of the observation sheet.

The observed information was gathered on daily basis to decide the variation in output for the curved wall labour productivity on selected project sites. The observer would arrive on the site ahead of schedule as 7:00 am, note the progress of the work under observation, and record time of the work and delays experienced during the day and output from 7:00 am to 6:00 pm every day. The observed productivity data was collected over a total period of 12 weeks. The data collected were then used to calculate impact of learning on curved walls labour productivity. The investigation is a field study of actual data rather than data collection from recycled literature.

Data Analysis on Curved Walls Productivity

The least squares model which is similarly referred to as the linear regression model was adopted in the introductory statistical analysis of the study. The regression predictive model in this study was developed using the workers observed time to represent the dependent variable and the cycle numbers as the independent variables. The regression analysis was calculated using PHStat software that is normally used for Microsoft Excel. The relationship amid the curved wall inputs and cycle numbers was derived by substituting the observed recorded time into the straight-line linear regression model in equation 1: $Y = \alpha + \beta X$ …. 1.

From equation 1, α, and β demonstrates the intercept and the slant of the model. The intercept and the slant are predictable as thus:

$\beta = (n\sum xy-\sum x\sum y)/ (n\sum x2-(\sum x) 2)$ …. 2.

$\alpha = \bar{Y}-\beta\dot{X}$ …. 3.

In equation 3, Y, stand for the man-hours while X, signify the cycle numbers. The above equation α and β were utilised to appraise the regression model for the labour productivity of the curved wall.

The intercept and the slope were determined from the regression model in this manner:

$\beta = (n\sum xy-\sum x\sum y)/ (n\sum x2-(\sum x) 2)$, and $\alpha = \bar{Y}-\beta\dot{X}$. …. 4.

In equation 4, Y signifies the worker hours and X stand for the cycle numbers.

From the coefficient of correlation and regression model, α = 6.17, β= -0.09, y= -0.87. Where α stand for the intercept of the standard linear equation, β signify the slant of the linear curve, while y stand for the coefficient of correlation of the skill labour curved wall observed. The regression model for the curved wall labour observed was determined as Y = 6.17- 0.09X, where Y indicate workhours = 6.17 - 0.09 cycle numbers. From β, it shows that the relationship of the slop is negative, implying that there is a declining effect in working hours as the cycle numbers increases.

Influence of learning on curved wall productivity

The logarithmic straight-line expectation to learn and adapt is numerical express as:

$Y = TI\times (\times) b$ …. 5.

Where, Y stand for the man-hours or cost or time required to do the repetitive unit, while T1 signifies the cost or man-hours or time required to carry out the first unit, X stands for the cycle number of the unit and b is the slant of the learning curve, determined as:

$b=InS/ln2$ …… 6.

In equation 6, S= rate of learning, which is depicted as the percentage of unit input decrease, i.e., man-hours, cost or time, because of replication of the quantity number of units finished.

Therefore, we can re-write equation 6 as: $S= (2^b) *100$ …. 7.

Figure 1.0 represents the learning rate of the labour productivity of the curved wall in the project site observed. The x-axis stands for the cycle numbers while the y-axis signifies the man-hours.

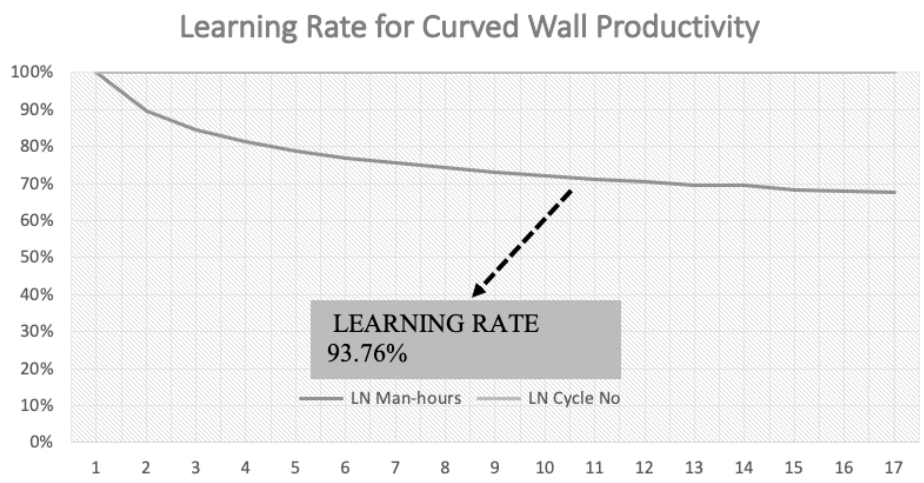


Figure 1. Relationship of Curved Wall operation and Cycle Numbers

The learning rate (S), communicated as a percentage, is measured by substituting the slant (b) appeared in equation 7, that is -0.09, into the learning rate equation as:

S = (2-0.09) x 100 = 93.76% as showed in figure 1.0. Table 1.0 illustrate learning rate table which was utilised in plotting the graph of the learning curve for the curved wall labour productivity observed. The LCT states that whenever the quantity of production of product doubles, the cumulative average cost or unit required for production, i.e., workers hours, cost, or time, decreases by a specific level of the past unit or total average rate. This rate is alluded to as the "learning rate" which recognise the learning accomplished. Also, it sets up the slant of the learning curve. The lower the learning rate, the more noteworthy learning is accomplished. A learning rate of 100% shows that no learning happens (Thomas *et al.,* 1986, Couto and Teixeira, 2005).

The learning rate reveals 93.76% which is significant for improving labour productivity in the construction industry. The study utilised 0.05% significance level as satisfactory degree of the inferences. A learning rate under 100% demonstrates that learning has happened and the justification of the LCT. The learning rate observed from this examination agrees with previous studies carried out in Vietnam, Asia (Long *et al.,* 2013). Jarkas (2010) found 96.40 and 92.90 per cent strong correlation and high coefficients of determination between labour productivity and the investigated factors. This finding is related with the findings of Jarkas (2010).

A learning rate under 100% demonstrates that learning has happened and the justification of the LCT. Figure 1.0 reveals a noteworthiness impact of learning on curved wall labour productivity, the productivity pattern created from figure 1.0, was observed to be concurrence with past examination on the impact of learning on labour productivity (Couto and Teixeira, 2005, Jarkas, 2010).

This investigation also compares with Thomas *et al.,* (1986) learning curve for construction operations. More precisely, it follows the 75 to 80 per cent trend of a learning curve, which applies to LCT of construction productivity. The learning influence observed in this study are consistently different from those of previous researchers (Jarkas, 2010, Ugulu and Allen, 2018, Thomas *et al.,* 1986, Couto and Teixeira, 2005). The significant productivity evaluation determinant observed in this

study could be attributed to two prime factors: the impact of learning as work advances and the effect of cycle time which influence the technique of construction.

S/N	LN Man-hours	LN Cycle No	C	D	E	F	G	H	I	J	K	L	M
	Y	X	XY	X2	n∑XY	∑X∑Y	n∑X2	β=I/J	Ẏ	Ẋ	Bẋ	α=Ẏ-Bẋ	S=2b*100
1	6.2300	-	-	-				-0.0929					93.7642
2	6.0400	0.6931	4.1863	0.4804									
3	6.0400	1.1098	6.7032	1.2317									
4	6.0300	1.3862	8.3588	1.9216									
5	5.9900	1.6094	9.6403	2.5902									
6	6.0000	1.7917	10.7502	3.2102									
7	6.0100	1.9459	11.6949	3.7865									
8	6.0200	2.0794	12.5180	4.3239									
9	5.9600	2.1972	13.0953	4.8277									
10	5.9900	2.3025	13.7920	5.3015									
11	5.9500	2.3978	14.2669	5.7494									
12	5.9100	2.4849	14.6858	6.1747									
13	5.9000	2.5649	15.1329	6.5787									
14	5.9900	2.6390	15.8076	6.9643									
15	5.8700	2.7080	15.8960	7.3333									
16	5.8600	2.7725	16.2469	7.6868	3,394.2338	3,410.2021	1,295.1930		5.9853	1.9715	-0.1831	6.1684	
17	5.9600	2.8332	16.8859	8.0270									
∑	101.7500	33.5155	199.6608	76.1878									

Table 1. Learning rate for learning rate for curved wall productivity

CONCLUSIONS

The study observed curved wall construction operation in a building project and the learning curve technique was adopted for the examination of labour productivity with the use of straight-line model. The effect of the learning curve on duration of project is shown. the curved wall labour productivity observed signifies an average learning of 93.76%, resulting in an improvement rate of 6.24% in labour productivity. This impact can decrease the duration of the project at an approximate rate of 1%-6%.

The study is restricted to a single site storey building with various floors because of the deductive nature of the study. The implication is that this research result may lack generalisation. However, the researchers proposed repeated experiment or observations with significant number of cycles, for examples observation of other building sites curved walls. It is important to note that the model developed in this investigation does not directly account for management skills and strategies or specific project conditions. However, it mirrors the straight-line learning model and its impact on labour productivity in the observed site. There are similarities in the various learning curve models. Therefore, there is need to advance research on differences in learning rate of labour using other models, i.e. the piecewise unit model, the exponential model and the cubic unit model of learning.

It is pertinent to note that based on observed parameters, method of construction was discovered as the most important parameter with great influence on curved wall productivity followed closely by height of the wall and the crew composition.

This research contributes to the development of models that can be utilised to examine the impact of learning on labour productivity. This model will help project managers and planners to view rate of labour productivity on a project in a learning curve diagram. This diagram will also help to determine labour progress rates and estimate crew's construction performance. The findings presented in this paper requires

mindful thoughts regarding effect of LCT on labour productivity in the construction industry.

REFERENCES

Bierman, M, Marnewick, A and Pretorius, J H C (2016) Productivity management in the South African civil construction industry - Factors affecting construction productivity, *Journal of South Africa Institution of Civil Engineering*, 58(**3**), 37-44.

Couto, J P and Teixeira, J C (2005) Using linear model for learning curve effect on high-rise floor construction, *Journal of Construction Management and Economics*, 23(**4**), 355-364.

Duff, A R, Pilcher, R and Leach, W A (1987) Factors affecting productivity improvement through repetition. *Managing Construction Worldwide*. London: Chartered Institute of Building (CIOB) 2, 634-645.

Durdyev, S and Mbachu, J (2018) Key constraints to labour productivity in residential building projects: evidence from Cambodia, *International Journal of Construction Management*, 18(**5**), 385-393.

Everett, J G and Farghal, S H (1997) Data presentation for predicting performance with learning curves, *Journal of Construction Engineering and Management*, 123(**1**), 46-52.

Franco, L A, Cushman, M and Rosenhead, J (2004) Project review and leaning in construction industry: Embedding a problem structuring method within a partnership context, *European Journal of Operational Research*, 152(**1**), 586-601.

Granadeiro, V, Duarte, J, Correia, R and Leal, V (2012) Building envelope shape design in early stages of the design process: Integrating architectural design systems and energy simulation, *Automation in Construction*, 1(**32**), 196-209.

Greve, H R and Audia, P G (2006) Sticky aspirations: Organizational time perspective and competitiveness, *Organizational Science*, 13(**1**), 1-17.

Jarkas, A M (2010) Critical investigation into the applicability of the learning curve theory to rebar fixing labor productivity, *Construction Engineering and Management (ASCE)*, 36, 1279-1288.

Kululanga, G, K, Price, A D F and Mccaffer, R (2002) Empirical investigation of construction contractors organizational learning, *Journal of Construction Engineering and Management*, 128(**5**), 385-391.

Leedy, P D and Ormrod, J E (2013) *Practical Research: Planning and Design 8th Edition*. Upper Saddle River, NJ: Prentice Hall.

Long, D, Nguyen, H and Nguyen, T (2013) The Relationship between building floor and construction labour productivity, *Engineering, Construction and Architectural Management*, 20(**6**), 563-575.

Love, P E D and Josephson, P E (2004) Role of error recovery process in projects, *Journal of Management in Engineering*, 20(**2**), 70-79.

Mashina, G and Gadi, M (2010) Intensity of solar radiation on convex walls using a new computerized tool. *In*: W Tizani (Ed.) *Proceedings of the International Conference on Computing in Civil and Building Engineering*, 30th June - 2 July, University of Nottingham, Nottingham University Press.

Missbauer, H and Hauber, W (2006) Bid calculation for construction projects: regulations and incentive effects of unit price contracts, *European Journal of Operational Research*, 171(3), 1005-1019.

Mohamed, B, Ayman, H, Sara, M E and Khaled, A (2019) How to predict the rebar labours' production rate by using ANN model? *International Journal of Construction Management*, 1(12), 2331-2327.

Naoum, S G (2016) Factors influencing labor productivity on construction sites. *International Journal of Productivity and Performance Management*, 65(**3**), 401-421.

Norwegian Building Research Institute (1960) *Developing the Exponential Model*, Norwegian Building Research Institute.

O'Leary, Z (2010) *The Essential Guide to Doing Your Research Project*. London: Sage Publications.

Ourghi, R, Al-Anzi, A and Krarti, M (2007) A simpliciter analysis method to predict the impact of shape on annual energy use for office buildings, *Energy Conversion and Management*, 48(**1**), 300-305.

Rao, B P, Sreenivasan, A and Prasad, B N (2015) Labor productivity: Analysis and ranking, *International Research Journal Engineering Technology*, 2(**3**), 151.

Thomas, H, Mathews, C T and Ward, J G (1986) Learning curve models of construction productivity, *Journal of Construction Engineering and Management*, 112(**2**), 245-258.

Thomas, H and Zavrski, I (1999) Construction baseline productivity: Theory and practice. *Journal of Construction Engineering and Management*, 125(**5**), 295-303.

Tran, V and Tookey, J (2011) Labour productivity in the New Zealand construction industry: A thorough investigation, *Australasian Journal of Construction Economics and Building*, 11(**1**), 41-60.

Ugulu, R A and Allen, S (2018) Using the learning curve theory in the investigation of on-site craft gangs' blockwork construction productivity, *Built Environment Project and Asset Management*, 8(**3**), 267-280.

Wong, P, Cheung, O, Yiu, R Y and Hardie, M (2012) The unlearning dimension of organisational learning in construction projects, *International Journal of Project Management*, 30 (**1**), 94-104.

THE PRODUCTIVITY, PERFORMANCE AND QUALITY PARADOX: AN ALTERNATIVE PERSPECTIVE

Lloyd Scott[1] and Sittimont Kanjanabootra[2]

[1] *School of Surveying and Construction Management, Technological University Dublin, City Campus, Dublin 1, Ireland*

[2] *School of Architecture and Built Environment, Faculty of Engineering and Built Environment, University of Newcastle, Callaghan NSW 2308, Australia*

Productivity, quality and flexibility are critical measures of performance for justifying the investment in manufacturing and production systems, including construction. Existing knowledge in Architecture Engineering and Construction (AEC) informs us that performance, productivity and quality are interconnected through conventional measures, focused on cost but which are implemented in practice through trade-offs affecting one or more in project outcomes. This paper offers a theoretical discussion which aims to create a dialog on how the AEC sector should evaluate the roles of both traditional cost-focused measurement and non-traditional measurement methods. Investing in people, both as a stock of knowledge and having expertise could be a way to increase productivity which, as extant research shows, will have on-going positive effects on both quality and performance.

Keywords: performance, efficiency, quality, paradox, value

INTRODUCTION

Extant research and theory posit that performance, quality and productivity constitute a paradox for the AEC sector. Construction business organisations aim for all three, yet they understand, from an economic perspective, that attainment simultaneously is often difficult at best. Trade-offs become an integral part of the process of decision-making in construction as limited resources and finite budgets force choices between performance, quality and productivity (the 3 Ps). Making decisions requires trading off one item against another. In economics, the term trade-off is often expressed as an opportunity cost, which is the most preferred possible alternative. A trade-off involves a sacrifice that must be made in order to get a specific outcome. This paper offers then a theoretical discussion which aims firstly, to review relevant arguments about performance, quality and productivity and how they related to trade-off, and secondly to create a dialog on how the AEC sector can look at non-traditional measuring methods. It is proposed that by investing in people (Human Capital) both being a stock of knowledge and having expertise, as a way to increase productivity which, as existing research shows, will have on-going positive effects on both quality and performance, and enable trade-offs to be reconsidered in ways that do not reflect costs and the bottom-line alone. Many authors have written on the 3 Ps independently, however when the three are considered as an entity there is a dearth of

[1] lloyd.scott@dit.ie

Scott, L and Kanjanabootra, S (2019) The Productivity, Performance and Quality Paradox: An Alternative Perspective *In:* Gorse, C and Neilson, C J (Eds) *Proceedings of the 35th Annual ARCOM Conference,* 2-4 September 2019, Leeds, UK, Association of Researchers in Construction Management, 134-142.

research that has been shared on this topic. The authors are of the view that much needs to be done to explore and develop this topic. We ask then:

how will construction organisations gain the best possible chance of achieving performance, productivity and quality goals, and subsequently minimise the need for trade-offs and maximise business value in a construction project, other than by cost?

The Paradox of Performance, Productivity and Quality

In trying to establish an argument about the interrelationships of performance, productivity and quality, it is essential to understand business intent or strategy. Porter (1980; 1985) argues that the fundamental purpose of strategy is the creation of business value concentrating on cost leadership, product or process differentiation, and/or focus. Porter argues that the creation of business value represents the essence of strategy, but that value needs to be measured. Performance Management is the most accepted means of measurement of business value created by strategy through a multitude of measurement systems such as 6-Sigma, TQM, BPM, PRR, etc. However, the focus here is not on these systems but on trying to tease out where the sources of value, the factors of production, can be used to enable some form of solution to what is seen as a paradox. In the literature some argue that productivity and quality are interconnected others argue that quality and performance, and productivity can performance are also interconnected. All are considered valid. Yet the interconnected nature of all three produces differing interpretation again all considered valid but unresolved.

Performance is argued by Rolstadas (1998) to be a complex relationship involving seven performance criteria: effectiveness, efficiency, quality, productivity, quality of work, innovation and profitability. Performance is essentially defined by a performance management system, a collection of specific metrics designed for multiple purposes: management accounting, strategy evaluation, or financial actions (Bossioni *et al.,* 2004; Franco-Santos *et al.,* 2007). In the AEC literature, performance is defined by how it is measured (Yang *et al.,* 2010; Love and Holt 2000; Cain 2008). Essentially construction projects and organisational performance are assessed by a set of ratios evaluating the relationships between the costs of inputs (labour, capital) and the benefits created as outputs (Kagioglou *et al.,* 2001; Ali *et al.,* 2010). Four sets of measurements are used and usually set as KPIs (Liu *et al.,* 2014; Beatham *et al.,* 2004). The first, financial performance, uses ratios of profitability, growth, financial stability and cash flow (Yu *et al.,* 2007). The second, customer relationship performance is measured by ratios that assess the quality of service and work (El-Mashaleh *et al.,* 2007), or that measure external customer satisfaction (Rankin *et al.,* 2008), or measure market share (Yu *et al.,* 2007). Thirdly, the literature identifies measures of internal business performance with ratios assessing safety (El-Mashaleh *et al.,* 2007; Rankin *et al.,* 2008), business efficiency and the effectiveness of planning (Yu *et al.,* 2007). Fourthly and more recently, measures of sustainability performance are being incorporated and assessed as part of the creation of value as integral to business strategy (Teh and Corbitt 2017).

However, this traditional approach does not capture other aspects that relate to performance (Neely *et al.,* 2001). Bassioni *et al.,* (2004) reviewed contemporary performance measurements in construction and argued for the inclusion of non-cost measures, quality, time, process, and flexibility, the earlier proposals of Cross and Lynch (1988) offered a performance pyramid that included a company's vision, market measures, finance measures, customer satisfaction, flexibility, productivity,

quality, delivery, process time, cost and operations. In contemporary business performance these outcomes are collated and most often measured as the Triple Bottom Line (Elkington 1998; 2013). One of the key elements we believe missing from this work, there could be others, is the value created by knowledge stocks, and the expertise of human capital as each contributes to performance, productivity and quality.

The Relationship Between Productivity and Performance and Quality

Productivity of any resource has been characterised by the OECD as a ratio of yield to inputs utilised for a specific activity of a process in the production of goods, services or any other product and construction (OECD, 2001). The existing research highlights some of the factors affecting construction productivity, namely rework, poor supervisor competency and incomplete drawings (Hughes *et al.,* 2014); unwell pre-construction planning, mismanagement of materials onsite and overcrowded tradesmen on site, change of scope of work and excessive variation order (Noaum 2016); and errors or inconsistencies in project documents, lack of requirement specifications in tender documents, and unforeseeable authority requirements or restrictions (Larsen *et al.,* 2015). Each in turn increases time-cost, resources cost and labour costs.

Performance is positively correlated to productivity (Arashpour and Arashpour 2015). However, that research sometimes, inadvertently, identifies the necessary role of trade-offs between elements of efficiency and the attainment of performance goals. In the traditional economics-driven business model, choices are made between the keys factors of production, the price of labour and the price of capital (investment in resources, machinery). The maximization of profit (performance) for a given level of expenditure (budget) is a ratio of these two. This ratio represents a way of perceiving, albeit simply, the relationship between productivity and performance. The determination of profit will vary between construction projects but inevitably there is a decision-making process where trade-off decisions are made to maximize the ratio of the two.

None the less, the modern economy is being disrupted by new inputs into the determination of productivity and therefore performance. Knowledge resources and the adoption of KM in construction has been shown to reduce the inefficiencies of operations (Al-Qubaisi *et al.,* 2018). These knowledge resources are sometimes translated into capital as either new technologies and/or new innovations. BIM for example has the potential to replace the paper-based tools of construction projects, with a digital environment improving levels of efficiency, exceeding those of traditional construction processes (Lee, 2008). Bryde *et al.,* (2013) showed that cost was the one most positively influenced by the implementation of BIM followed by time, communication, coordination improvement and quality. Each new technology input has a distinct cost (cost of software, cost of hardware, increased labour costs to purchase expertise for implementation and operations) and thus a price. However, there is an extended argument that the 'new' or 'the innovation' brings greater benefits by decreasing the price of 'normal labour' as there is less needed or less time is needed in the construction process. This is often wishful thinking as the research about technology and innovation adoption would suggest otherwise, increased time, increased cost and increased complexity. For example, Trkman (2010) refers to the return/evaluation of IT investments, which he indicates has been a challenge across all industries in the last four decades. On the other hand, Brynjolfsson and Hitt (1996)

argue that this is a phenomenon in the short run only and often resolves in the longer term, a dilemma when the expectancy of investment in innovations like IT is short run return. Carillo *et al.,* (2013) show that the implementation of KM systems, for example, is often ad hoc and adopted in an environment where expectations are that the system itself generates benefits. It is humans who generate benefits from technology adoption. This argument remains unresolved. However, knowledge, technologies and innovations are grounded in investment in human capital, the source of expertise. Again this suggests that alternative measures other than costs alone should be included in business models in construction, as a key element in the development of productivity, the attainment of quality and the achievement of business performance and value.

In the Construction literature quality is most commonly defined as conformance to requirements meeting customer expectations (Ali 2010). Often quality is assessed in construction against strict criteria in quality management systems such as ISO, TQM, JIT, BPR, Balanced Scorecard and 6 Sigma (Daniel 2016; Willar *et al.,* 2016). Such itemization of quality is mandated in construction in many countries (Ofori *et al.,* 2000; Turk 2009). The assumption of quality management systems is that adherence to quality processes will lead to measurable quality improvement. QM practices contribute to operational and financial performance, allowing a firm to achieve competitive advantage (Kim *et al.,* 2012). Construction productivity would be affected adversely if the materials required for use are not available in the quantity or quality required when they are needed (Pheng 2001; Pheng and Meng 2018). Mahmood *et al.,* (2014) highlighted this relationship between poor quality and productivity in projects. If quality is poor it negatively impacts on performance through increased costs and poor productivity.

Conventional wisdom offers that productivity, quality and flexibility are critical measures of performance for justifying the investment in manufacturing and production systems, including construction. Existing knowledge in construction informs us that performance, productivity and quality are interconnected through conventional measures. For example, if productivity increases, performance most probably also increases and vice versa. (Karunarate 2015). However, this conventional perspective is focused on cost and value production as profit. Essentially the existing research literature and theory proposes a business model based on the following general propositions, which can be represented as a simple model as shown in Figure 1 where decision making is reflected through the trade-offs made between each of performance, productivity and quality:

- Performance is measured through cost/benefit ratios;
- If productivity increases performance increases and vice versa;
- If resources increase, productivity increases;
- If quality is poor, productivity will decrease;
- If quality is poor, little business value is created;
- Quality is a good measure of performance;
- Expertise has positive effect on performance;
- If productivity improves, it will improve expertise?
- Implementation of Quality Management Systems will increase performance;
- Productivity, quality and flexibility are critical measures of performance.
- There is a positive correlation between performance and innovation.

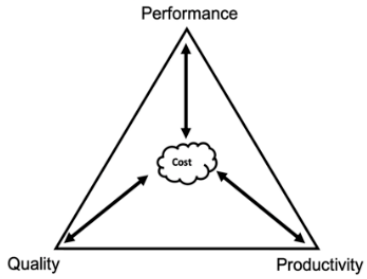


Fig: 1 The conventional construction business model

However, the very important point here is that the model makes no recognition of the effects of the disruptors or of the explicit value created by human capital. Human capital is a source of knowledge and expertise of the organization which subsequently will bring innovation to the organization. Human Capital are the elemental knowledge storehouses of organisations (Egbu, Botterill and Bates, 2001) which provide the intellectual capital that facilitates both efficient management and the possibilities of innovation adoption (Egbu and Robinson 2005).

An Alternative Business Model in Construction

In seeking to increase Performance, Productivity and Quality overall, it is important to look at the whole as well as the parts of a system and to understand how each part interacts with the others. History suggests there are deep-seated problems holding construction back as it struggles to improve performance and quality along with raising productivity (eg. Al-Qubaisiet al., 2018; Arashpour and Arashpour 2015). The argument here is that quality, productivity and performance are tangled in a traditional TQM like chicken and egg and centered by cost. For example, if an organization increase performance the productivity will also increase but quality also has impact on performance. For example, if a company finish construction project fast (this mean high performance) but the quality is not up to scratch and the building is full of defects. Therefore, you cannot say that that company has high performance.

Previous research outside construction identifies the role of human resources in business performance (Young and Berman 1997). More recently the research literature has focused on the role of expertise (Chan 2016; Mogendorff 2016) knowledge and the value they create in construction. That expertise can become an investment in human capital and therefore, we argue, can generate a focus on knowledge resources as a co-focus with cost within the business model (Fig 2)

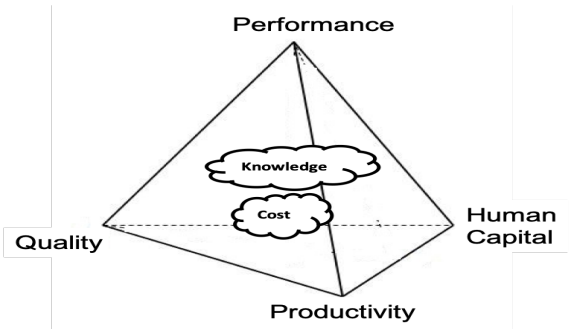


Fig: 2 Alternative business model in construction

What is not evident here, and certainly not in the conventional construction business model, (Fig 1) is an understanding of how these might enable moderation of the trade-

offs necessary in the conventional model. The existing research literature often shows the relationships between performance and various elements including finance, time, health and safety, functionality and the last two elements of our conundrum, quality and productivity (eg. Bossioniet al., 2004; Franco-Santoset al., 2007; Love and Holt 2000). It is argued here that there is no explicit established relationship between performance and knowledge and expertise. It appears that there is an implicit assumption that knowledge and expertise already exist in the business equation creating value. This begs a number of questions for research: how can a relationship between performance and knowledge and expertise be measured? What will the impact of that relationship be on quality and productivity?

As referred to earlier, the conventional wisdom is that productivity, quality and flexibility are critical measures of performance for justifying the investment in AEC sector. A 'compartmentalised' approach to knowledge management and expertise in this area is somewhat problematic, however, it is not entirely the fault of the sector as it has a plethora of disparate mandates ranging from security to education, legal interpretation, health, and service delivery and to harmonise knowledge expertise approaches across all would be a tall order. In order for the AEC sector to capitalise on the benefits of knowledge and expertise it is essential for it to overcome the cultural barriers that permeate its hierarchies by increasing teamwork, reducing bureaucratic decision making and increasing value management. With the advent of new public sector project structure in many regions, a less compartmentalised management regime for projects and the drive for cultural and efficiency changes, tomorrow's public sector projects could be less of a mystery and more of an open, transparent and practical service which will benefit public interest and so society. silo

CONCLUSION

As the diverse nature of the AEC sector, a 'one size fits all' solution is not applicable, for example, knowledge expertise delivery in house building sector, for example is subject to completely different parameters than knowledge and expertise applied through their application in infrastructure pharmaceutical projects. There have been few frameworks in the literature aimed at identifying the disparate nature of knowledge expertise and no single framework aimed at identifying individuals in the AEC sector and attempting to capture the knowledge/ expertise they hold.

A framework put forward that attempts to look at AEC sector knowledge expertise from an overarching perspective, which gives the reader an insight into high level AEC sector specific attributes. A way of developing this might be through communities of practice (COP). COP have been researched with the specific issues that are conducive to its proliferation in the public sector being discussed, such as its propensity to facilitate knowledge sharing, but in order to be successful, communities of practice must have management recognition, potential rewards, and requisite IT infrastructures.

The suggestion then is that collaborative performance in projects (joint specification, selected tendering, soft parameters in bid evaluation, joint subcontractor selection, incentive-based payment, collaborative tools, and contractor self-control) generally have a positive influence on project performance (cost, time, quality, environmental impact, work environment, and innovation). It is additionally proposed that these relationships are moderated or mediated by the collaborative climate (i.e. the trust and commitment among partners) in the project and moderated by the overall project characteristics (i.e. how challenging the project is in terms of complexity,

customisation, uncertainty, value/size, and time pressure). Based on this contribution, future research can, once developed, test any framework empirically to further increase the knowledge about how expertise and the impact on productivity and performance factors may influence project success.

REFERENCES

Ali, A S and Rahmat, I (2010) The performance measurement of construction projects managed by ISO-certified contractors in Malaysia, *Journal of Retail and Leisure Property*, 9(**1**), 25-35.

Al-Qubaisi, S S, Ajmal, M M and Khan, M (2018) Impact of knowledge management and ICT on operational efficiency: An empirical study, *International Journal of Knowledge-Based Development*, 9(**2**), 174-202.

Arashpour, M and Arashpour, M (2015) Analysis of workflow variability and its impacts on productivity and performance in construction of multistorey buildings, *Journal of Management in Engineering*, 31(**6**), 04015006.

Bassioni, H A, Price, A D and Hassan, T M (2004) Performance measurement in construction, *Journal of Management in Engineering*, 20(**2**), 42-50.

Beatham, S, Anumba, C, Thorpe, T and Hedges, I (2004) KPIs: A critical appraisal of their use in construction, *Benchmarking: An International Journal*, 11(**1**), 93-117.

Bryde, D, Broquetas, M and Volm, J M (2013) The project benefits of building information modelling (BIM), *International Journal of Project Management*, 31(**7**), 971-980.

Brynjolfsson, E and Hitt, L M (1996) Paradox lost? firm-level evidence on the returns to information systems spending, *Management Science*, 42(**4**), 541-558.

Cain, C T (2008) *Performance Measurement for Construction Profitability*. Chichester, West Sussex: John Wiley and Sons.

El-Mashaleh, M S, Edward Minchin Jr, R and O'Brien, W J (2007) Management of construction firm performance using benchmarking, *Journal of Management in Engineering*, 23(**1**), 10-17.

Carrillo, P, Ruikar, K and Fuller, P (2013) When will we learn? Improving lessons learned practice in construction, *International Journal of Project Management*, 31(**4**), 567-578.

Chan, P W (2016) Expert knowledge in the making: Using a processual lens to examine expertise in construction, *Construction Management and Economics*, 34(**7-8**), 471-483.

Chan, A P (2004) Key performance indicators for measuring construction success, *Benchmarking: An International Journal*, 11(**2**), 203-221.

Cross, K F and Lynch, R L (1988) The SMART way to define and sustain success, *National Productivity Review*, 8(**1**), 23-33.

Daniel, S (2016) *Performance Improvement in Quality and Productivity of Construction Projects Based on TQM and Six Sigma Principles*.

Egbu, C and Robinson, H S (2005) Construction as a knowledge-based industry, *In*: C J Anumba, C Egbu and P Carrillo (Eds.) *Knowledge Management in Construction*, 31-49.

Egbu, C O, Botterill, K and Bates, M (2001) The influence of knowledge management and intellectual capital on organizational innovations. *In: A*kintoye, A (Ed.), *Proceedings of the 17th Annual ARCOM Conference*, 5-7 September 2001, Salford, UK. Association of Researchers in Construction Management, Vol. 1, 547–55.

Elkington, J (1998) Partnerships from cannibals with forks: The triple bottom line of 21st-century business, *Environmental Quality Management*, 8(**1**), 37-51.

Elkington, J (2013) Enter the triple bottom line, *In*: A Henriques and J Richardson (Eds.) *The Triple Bottom Line*. Abingdon: Routledge, 23-38.

El-Mashaleh, M S, Edward Minchin Jr, R and O'Brien, W J (2007) Management of construction firm performance using benchmarking, *Journal of Management in Engineering*, 23(**1**), 10-17.

Franco-Santos, M, Kennerley, M, Micheli, P, Martinez, V, Mason, S, Marr, B, Gray, D and Neely, A (2007) Towards a definition of a business performance measurement system, *International Journal of Operations and Production Management*, 27(**8**), 784-801.

Idrus, A, Sodangi, M and Husin, M.H (2011) Prioritizing project performance criteria within client perspective, *Research Journal of Applied Sciences, Engineering and Technology*, 3(**10**), 1142-1151.

Hughes, R and Thorpe, D (2014) A review of enabling factors in construction industry productivity in an Australian environment, *Construction Innovation*, 14 (**2**), 210-228.

Idrus, A, Sodangi, M and Husin, M.H (2011) Prioritizing project performance criteria within client perspective, *Research Journal of Applied Sciences, Engineering and Technology*, 3(**10**), 1142-1151.

Kagioglou, M, Cooper, R and Aouad, G (2001) Performance management in construction: A conceptual framework, *Construction Management and Economics*, 19(**1**), 85-95.

Kaplan, R S and Norton, D P (1992) The Balanced Scorecard: Measures that drive performance, *Harvard Business Review*, (January-February) 71-9.

Karunaratne, N D (2015) The productivity paradox and the Australian mining boom and bust, *Research in World Economy*, 6(**1**).

Kim, D Y, Kumar, V and Kumar, U (2012) Relationship between quality management practices and innovation, *Journal of Operations Management*, 30(**4**), 295-315.

Larsen, J K, Shen, G Q, Lindhard, S M and Brunoe, T D (2015) Factors affecting schedule delay, cost overrun and quality level in public construction projects, *Journal of Management in Engineering*, 32(**1**), 04015032.

Lee, C (2008) BIM: Changing the AEC Industry, *PMI Global Congress 2008*, Project Management Institute, Denver, Colorado, USA.

Liebeskind, J (1996) Knowledge, strategy and the theory of the firm, *Strategic Management Journal*, 17, 441-52.

Love, P E and Holt, G D (2000) Construction business performance measurement: the SPM alternative, *Business Process Management Journal*, 6(**5**), 408-416.

Liu, J, Love, P E, Davis, P R, Smith, J and Regan, M (2014) Conceptual framework for the performance measurement of public-private partnerships, *Journal of Infrastructure Systems*, 21(**1**), 04014023.

Mahmood, S, M Ahmed, S, Panthi, K and Ishaque Kureshi, N (2014) Determining the cost of poor quality and its impact on productivity and profitability, *Built Environment Project and Asset Managemen*t, 4(**3**), 296-311.

Mogendorff, K (2016) The building or enactment of expertise in context: what the performative turn in the social sciences may add to expertise research in construction management, *Construction Management and Economics*, 34(**7-8**), 484-491.

Naoum, S G (2016) Factors influencing labor productivity on construction sites: A state-of-the-art literature review and a survey, *International Journal of Productivity and Performance Managemen*t, 65(**3**), 401-421.

Neely, A, Adams, C and Crowe, P (2001) The performance prism in practice, *Measuring Business Excellence*, 5(**2**), 6-13.

Ofori, G, Briffett IV, C, Gang, G and Ranasinghe, M (2000) Impact of ISO 14000 on construction enterprises in Singapore, *Construction Management and Economics*, 18(**8**), 935-947.

Oliver, G B M (1990) *Quality Management in Construction: Interpretations of BS 5750 (1987)-'Quality Systems' for the Construction Industry*. Construction Industry Research and Information Association.

Pheng Low, S (2001) Quantifying the relationships between buildability, structural quality and productivity in construction, *Structural Survey*, 19(**2**), 106-112.

Pheng, L S and Meng, C Y (2018) *Managing Productivity in Construction: JIT Operations and Measurements*. Abingdon: Routledge.

Porter, M E (1980) *Competitive Strategy*, New York: Free Press.

Porter, M E (1985) *Competitive Advantage*, New York: Free Press.

Porter M (1991), Towards a dynamic theory of strategy, *Strategic Management Journal*, 12(**2**), 95-117.

Reijers, H A, Mendling, J and Recker, J (2015) Business process quality management, *In*: *Handbook on Business Process Management 1*. Berlin: Springer, 167-185.

Rolstadas, A (1998) Enterprise performance measurement, I*nternational Journal of Operations and Production Management*, 18(**9-10**).

Taticchi, P, Tonelli, F and Cagnazzo, L (2010) Performance measurement and management: A literature review and a research agenda, *Measuring Business Excellence*, 14(**1**), 4-18.

Teh, D and Corbitt, B (2015) Building sustainability strategy in business, *Journal of Business Strategy*, 36(**6**), 39-46.

Trkman, P (2010) The critical success factors of business process management, *International Journal of Information Management*, 30(**2**), 125-134.

Turk, A (2009) The benefits associated with ISO 14001 certification for construction firms: Turkish case, *Journal of Cleaner Production*, 17(**5**), 559-569.

Willar, D, Trigunarsyah, B and Coffey, V (2016) Organisational culture and quality management system implementation in Indonesian construction companies, *Engineering, Construction and Architectural Management*, 23(**2**), 114-133.

Wong, J K W, San Chan, J K and Wadu, M J (2016) Facilitating effective green procurement in construction projects: An empirical study of the enablers, *Journal of Cleaner Production*, 135, 859-871.

Yang, H, Yeung, J F, Chan, A P, Chiang, Y H and Chan, D W (2010) A critical review of performance measurement in construction, *Journal of Facilities Management*, 8(**4**), 269-284.

Yeung, A.K and Berman, B (1997) Adding value through human resources: Reorienting human resource measurement to drive business performance, *Human Resource Management*, 36(**3**), 321-335.

Yu, L, Kim, K, Jung, Y and Chin, S (2007), Comparable performance measurement system for construction companies, *Journal of Management in Engineering*, 23(**3**), 131-9.

CAN WE REALLY MEASURE CONSTRUCTION PRODUCTIVITY?

Toong Khuan Chan[1] and Shang Gao

Faculty of Architecture Building and Planning, University of Melbourne, Parkville, Victoria 3010, Australia

Recent studies have highlighted that productivity growth for the construction industry have remained stubbornly low or have declined over the last two decades in many developed countries. This observation does not match the advances in materials, project management, procurement, information technology, and increasing specialisation or broad globalised operations that has characterised these modern construction companies. While recent projects are built under more onerous regulatory, health and safety, environmental and quality expectations, these changes are often not considered when productivity measures are calculated. This study critically reviews both the economic and physical measures of productivity from data and methodological perspectives to determine the sources of errors and discrepancies in the computation of productivity measures. Estimates of construction productivity based on identical data sets in the US indicate that these economic productivity measures are very sensitive to the choice of the price deflators. More recent estimates report improvements in productivity using revised deflators. In contrast, physical productivity measures do not suffer from these limitations. Furthermore, market factors and recent changes to the structure of the construction supply chain have led to new challenges in the computation of these estimates. Labour hire and equipment leasing arrangements, offsite prefabrication and increasing use of imported intermediate products shift a large proportion of work away from the construction sector. This leaves the less productive site assembly tasks to be carried out by construction companies. In a highly competitive market, productivity gains in the construction sector are often lost to other sectors of the economy through low profit margins. This review suggests that traditional approaches to construction productivity may no longer be applicable in a modern construction industry. Adopting a value chain approach to construction productivity where all stages of production including the supply and manufacture of intermediate products are analysed may be a better solution to enable the identification of the underlying factors of productivity.

Keywords: market forces, construction productivity, productivity growth, wages

INTRODUCTION

Global consulting firm McKinsey has reported that over the past twenty years the value added per hour worked in the construction sector has risen at a quarter of the rate of manufacturing (Barbosa *et al.,* 2017, Remes *et al.,* 2018). The average annual productivity growth rate of 1% from 1995 to 2015 is the lowest productivity gains of any industry. The trend is particularly concerning in advanced economies such as Germany and Japan where there was nearly no growth. McKinsey attributed the poor performance of the construction industries to increasingly complex projects, extensive

[1] tchan@unimelb.edu.au

Chan, T K and Gao, S (2019) Can We Really Measure Construction Productivity? *In:* Gorse, C and Neilson, C J (Eds) *Proceedings of the 35th Annual ARCOM Conference,* 2-4 September 2019, Leeds, UK, Association of Researchers in Construction Management, 143-152.

regulations, corruption, highly fragmented industry, mismatched risk allocations and rewards, inadequate design processes, poor project management, insufficiently skilled labour and under-investments in technology, equipment and machineries. They estimate that productivity would increase significantly if construction were to transform from a project-based approach to a manufacturing-like system of mass production. Their study relied extensively on research by Sveikauskas *et al.,* (2016) who observed that the productivity of construction in the US remained at the same level as 80 years ago with a consistent decline reported since the late 1960's.

This study seeks to critically review the evidence on productivity in the construction industry. Many studies on construction productivity are premised upon an assumption that the level of productivity in the construction industry had declined, not increasing or increasing at a rate that is low when compared to other sectors of the economy. There is an urgent need to re-examine the evidence objectively and review research that had subsequently re-analysed these productivity data. Therefore, the first objective is to examine the numerous definitions of productivity that are commonly used, and to identify the sources of data associated with these measures. In view of the number of studies reporting conflicting productivity results, the second objective is to review the methodologies adopted in these studies to determine the potential causes for these inconsistencies. While the literature lists numerous drivers that have been found to directly influence construction productivity, challenges such as the heterogeneity of construction outputs and issues in the definition of data continue to obscure the true measure of industry productivity. Comprehensive reviews on the drivers of construction labour productivity globally have been carried out by Crawford and Vogl (2006), Ruddock and Ruddock (2011), Yi and Chan (2013) and Green (2016) and will not be repeated here. In recent years, the construction markets in developed and developing countries have become extremely competitive with companies reducing margins further to win contracts, sub-contracting tasks that are risky or less profitable to other companies and seeking to procure intermediate inputs from a global supply chain. The third objective is to examine how wages, profitability, labour hire practices, greater use of prefabrication and global trade influences the estimate of construction productivity. The results are expected to shed light on the productivity measures that are most suitable for contemporary construction practices.

DEFINING PRODUCTIVITY

Basically, productivity can be described as the output achieved by a stated amount of input. For example, labour productivity can be defined as square metres of building completed (output) per man-days worked (input). Physical measures of labour productivity are often for activities at the task level and may not include the supervisory or management personnel. This definition of physical productivity is straight-forward and easy to compute but requires substantial effort by the builders to collect and report the activity and personnel information. Trade level measures can be aggregated to yield a project-level productivity indicator. Project-level indicators can then be weighted according to different project types and aggregated to produce an industry productivity indicator.

The use of a single factor productivity means that it is not possible to determine if the improvement is achieved though better work processes, greater use of plant and equipment, enhanced technology or better skilled workers.

Labour productivity can also be measured in terms of the gross value of the output (or as value added) and either man-hours or number of workers as the denominator. The use of dollar values for output is convenient as it allows work on different sub-sectors of the construction industry to be aggregated but the differences in labour intensity of these projects may conceal the true measures of productivity. Dollar values require adjustments to eliminate the effects of price changes over time: project price deflators accounts for inflation by converting output measured at current prices into constant-dollar values. International comparisons are further complicated by the choice of appropriate exchange rates although this may be mitigated somewhat by utilising purchasing power parities. Single-factor productivity indexes are not particularly useful to investigate causes of economic growth as the contribution of capital and other factors such as technological change that influence production are not captured.

A production function with two primary inputs labour (L) and capital inputs (K) and the construction output (Y) can be defined as Y = a f(L, K) through a production function (f) and a technology factor (a). This indicates that labour productivity is dependent on a technology function (a) and capital intensity (K/L). Additional investment in capital such as tools, equipment and machinery will in turn enhance the productivity of workers. Capital productivity, another measure of productivity that relates to a single factor - capital, is defined as a ratio of some measure of output to capital input (ABS 2016). Increased capital deepening means that each unit of labour has more capital to work with to produce output. Labour saving practices, such as automation, will result in increased capital deepening, which is often associated with a decline in capital productivity (but possibly offset by an increase in labour productivity). The computation of capital productivity in construction industry studies is problematic (Tan 2000).

The technology factor (a) or Total Factor Productivity (TFP) measures how labour and capital are used in combination to produce construction outputs. A more refined measure for productivity would be to consider labour, capital, material, energy and systems inputs into the production function, and to attribute all other un-measurable factors into a single variable (A). The KLEMS multifactor productivity estimate separates intermediate inputs into capital (K), labour (L), energy (E), materials (M) and services (S) to assist in evaluating how each input affects the production process (O'Mahony and Timmer 2009). Table 1 below list these productivity measures. Using the KLEMS database, Abdel-Wahab and Vogl (2011) found that there was a consistent slowdown in construction labour productivity growth across major OECD countries during the 1971 to 2005 period.

is There Evidence of Declining Productivity?

It is widely accepted that the industry today is building structures of greater complexity and higher quality than in the past and is doing so in shorter periods of time (Bernstein, 2003). On the other hand, major construction projects are often plagued with cost overruns and late delivery which may be indicators for lower productivities. Studies on construction industry productivity have been carried out since the 1950s for various countries using either the index approach, economic measures or a data envelopment analysis (Chancellor et.al 2019). The analyses of different time series and using different methods have resulted in widely varying findings of negative growth, stagnant or low growth in productivity. This review examines a series of successive research publications that rely only on common sets of labour and output data to assess the various methods of estimating productivity.

Table 1: Overview of main productivity measures (Source: OECD 2001)

Type of output measure	Labour	Capital	Capital and labour	Capital, labour and intermediate inputs
Gross output	Labour productivity (GO)	Capital productivity (GO)	Capital-labour MFP (GO)	KLEMS multi-factor productivity
Value added	Labour productivity (VA)	Capital productivity (VA)	Capital-labour MFP (VA)	-
	Single-factor productivity measures		Multi-factor productivity measures	

One of the first indications of a decline in construction productivity in the US was reported by Allen (1985) who reviewed data compiled by the Bureau of Labor Statistics (BLS) from 1950 to 1978. The data suggests that while the labour productivity (reported as value added per hour worked) rose at an annual rate of 2.2% between 1950 and 1968, it subsequently fell at an annual rate of 2.4% between 1968 and 1978. Using a deflator for building construction, Allen determined that half the observed decline in productivity during the second period was attributed to a deflator that was upwardly biased because it was largely based on cost data for labour and materials rather than actual building costs. The other half of the decline was attributed to a reduction in skilled labour intensity resulting from a shift in the mix of output from larger scale projects to single-family houses. Adopting a different labour productivity measure (i.e. value of contracts in real 1992 dollars/workhours), Teicholz *et al.,* (2001) also concluded that productivity declined at a compounded rate of 0.48% per year over the 1964 to 1999 period in the US. They attributed the decline to structural problems in the construction sector that prevented the adoption of labour-saving practices and better management processes that would reduce the use of on-site labour.

Conversely, Allmon *et al.,* (2000) showed that labour productivity had increased for all 20 tasks studied (i.e. labour cost per unit output has decreased) in the US construction industry from 1974 to 1996. All 20 tasks examined reflected a decreasing unit labour cost in real terms over a period of 25-30 years leading to an increase in productivity. This was in part driven by a decline in wages in real terms during the period of study. It appears that many of these productivity increases were due to technological improvements in the processes but in some areas where there were no significant technological changes, these increases must be attributed to labour productivity increases. In a re-analysis of earlier BLS data that indicated declines in construction productivity, Sveikauskas *et al.,* (2016) sought to produce better estimates of project price deflators. Using other official sources of project cost information to produce more reliable deflators in four sectors (office, educational, industrial and warehouse) of the construction industry, they observed clear and substantial productivity growth from Allen's (1985) BLS data. This finding clearly indicates that the correct choice of deflator is a significant determinant of the measure of productivity, and that previous observations of decline may be flawed. The sensitivity of these findings to appropriate estimates of project price deflators puts many of the findings of various industry reports and studies (Richardson 2014, Remes *et al.,* 2018, The Economist 2017) into doubt.

While a Productivity Commission (2014) report started that labour and multifactor productivity growth in the Australian construction industry stagnated in the mid-1980s to the mid-1990s but increased from the mid-2000s, it stressed that the source and credibility of this growth was uncertain. Similarly, in a study of productivity data from the US, Rojas and Aramvareekul (2003) considered data for the 1979-1998

period from the Bureau of Economic Activity (BEA) and the BLS to be too unreliable to be useful in the generation of productivity measures. They attribute the discrepancy to the use of project data rather than establishment data that was less reliable, and to the level of aggregation. They assert that the output mix alone can severely distort labour productivity values by large percentages rendering many observations erroneous.

Data produced by the Singapore Building and Construction Authority (BCA 2019) indicates consistent improvements in project productivity in 6 building categories

This review suggests that many challenges still exist in the estimation of productivity when cost or price data is being considered, and there is considerable debate on the best approach. In comparison, attempts to compute physical productivity such as those by the Singapore Building and Construction Authority (BCA 2019) indicate consistent improvements in project productivity in 6 building categories.

Challenges in the Estimation of Productivity

Construction companies today operate in a highly competitive market with low profit margins and is characterised by increasing specialisation and fragmentation of work and processes. Building materials, intermediate inputs and sub-contract labour are now sourced from a wider geographical region, often from lower-wage regions or lower-cost producers in Central America, Eastern Europe or Asia leading to a globalised supply chain. These changes in market structure and economic factors add to the numerous challenges that already exist in the estimation of construction productivity.

Definition of labour productivity and boundaries of production
While physical measures of labour productivity are easy to compute, it is necessary to consider the boundary of the production process; i.e. if labour input should focus solely on the workers involved in the task or include supervisory and management staff. This is acceptable if the productivity measure is at the task or activity level but may under-estimate the labour input if these measures are aggregated into a firm or industry level estimate. Productivity measures utilising gross output represents the total project value which includes intermediate inputs from the manufacturing, transport and retail sectors that are incorporated into the completed building. Value added, which is defined as the difference between the total revenue of an industry and the total cost of intermediate inputs, is often more representative of the contribution of labour and capital to the production process, and as such is derived by summing factor incomes; i.e. compensation of employees, gross operating surplus and gross mixed incomes. Labour productivity measures derived from national accounts data are based on value added whereas those resulting from industry data are based on gross output leading to further confusion. The use of value added per worker as a measure of labour productivity in construction must consider the high value added when wages and profits are high during a boom period and the converse during a downturn.

Labour hire arrangements
Modern construction companies generally operate as management contractors with minimum direct labour hire, preferring to engage sub-contractors or labour hire companies to carry out most of the construction work. This provides more flexibility (i.e. avoid having permanent staff on payroll, less onerous employee entitlements) in engagement of tradesmen but is often criticised as an arrangement where the workers receive lower wages, few benefits and no training (CFMEU, 2015). The use of labour

hire companies severely misrepresents the number of workers in the construction industry if labour hire companies are classified as part of the services sector.

Capital intensity

The impact of capital in the computation of labour productivity can be traced back to the 1950s when Robinson (2013) questioned the estimate of the value of capital goods in the Cobb-Douglas production function and the associated marginal productivities. The best available estimate of capital is the value of net fixed assets of construction companies. These are depreciated using a straight-line method at appropriate rates of between 10% to 30% per annum for vehicles, machinery and equipment (Tan, 2000). Tan cited difficulties in estimating capital assets such as buildings during the peak of a property cycle where the value of these assets may be extremely high. Other challenges include the separation of the development or investment property assets owned by construction companies. Furthermore, capital assets are valued at historical cost and capacity utilisation of machinery and equipment are often not considered.

Leasing of equipment and machinery

The issue of capital intensity is further compounded by construction companies leasing equipment such as tower cranes, concrete pumps, and excavators from rental or hire companies that will be recorded as expenses in the intermediate inputs. A company that leases rather than purchases capital equipment will understate capital intensity.

Wages

Higher wages will reflect higher value added and therefore leads to a higher labour productivity. This discrepancy was pointed out by Low (2015) when he compared the hourly wages for general labour for Singapore and the US in 2012, suggesting a higher labour productivity in the US based on wage alone notwithstanding any actual differences in physical labour productivity.

Profits

Profit (as gross operating surplus) is another component in the computation of value added that directly contributes to labour productivity. However, the level of profit a company attains is not only dependent on its efficiency in construction activities but largely dictated by market forces. In a highly competitive market, productivity gains are passed on to customers in the form of lower prices rather than higher company profitability. The decline in profitability of Canadian construction firms from 5-6% between 1980-1990 to 1-2% between 1992-2001 resulted in the reduction of value added leading to a consequential decline in the productivity measure (Bernstein 2003).

Off-site prefabrication and embodied labour

With the increasing amount of prefabrication that is taking place, the work that is carried out off-site is captured in the manufacturing sector, potentially reallocating the improvements in productivity to the manufacturers as opposed to the construction sector. The value of off-site prefabrication may be considerable when increasingly larger assemblies such as bathroom pods and curtain wall units are being prefabricated. The transfer of work off-site raises many new issues and their analysis requires a clear demarcation of the boundaries of the construction sector to be studied. Shifting work offsite dramatically reduces the demand for on-site workers and results in significant improvement in physical labour productivity. Off-site construction is generally more productive due to the use of machinery in place of workers and the adoption of manufacturing processes. In time, tasks that remain on-site are those that are labour intensive and cannot be easily automated.

Another important issue in prefabrication is the concept of embodied labour when building components are pre-assembled or manufactured off-site. The primary inputs of labour and capital required to produce these components in the factory are attributed to the manufacturing sector. These assemblies are procured as intermediate products with an embodied labour content but are not accounted for in labour productivity measures. While there is evidence from Singapore (BCA 2019) that indicates improvements in on-site labour productivity in highly repetitive high-rise public housing and institutional buildings, the embodied labour input of off-site production of prefabricated components is not captured.

Expansion of Global Value Chains

In recent years, the increase in global trade as a result of manufacturing moving from G7 countries into Eastern Europe, North America into Central America and the rise of China as a manufacturing powerhouse has also affected the source of intermediate inputs into the construction industries of many developed economies. Labour shares in developed economies continue to fall as more companies participate in these global supply chains and increase trade integration with lower cost producers worldwide (Baldwin 2016). The effects of this phenomenon are not unlike that of off-site prefabrication where value added is lost to manufacturing, leaving the more unproductive site assembly to be carried out by the construction companies.

Recent changes in the structure of the construction industry and the broader fragmentation of its activities have presented new challenges to the measurement of productivity. These factors add further complexity to an already difficult problem.

Suggestions for Better Measures of Productivity

Economic measures of productivity are fraught with difficulties in the definition of productivity measures, data collection and market issues as discussed in the previous section. On the other hand, physical measures of productivity fail to capture the embodied labour of offsite production or productivity measures in the manufacture of intermediate inputs.

In a recent editorial on rethinking construction productivity theory and practice, Pan (2018) concluded that consistency of measure is never going to be achievable. None of the papers in the special issue of Built Environment Project and Asset Management (2018) suggested new or improved methods of producing construction productivity measures, nor how to better collect productivity data. Forsythe (2018) suggested dividing the measurement effort into two distinct parts: A homogeneous component to enable project-to-project comparisons to be made, and a heterogeneous component that caters to the vast variance in the type of projects that are carried out. The difficulties on how to make sense of the heterogenous component remain unresolved.

The fragmentation of labour into labour hire arrangements and sub-contracts, and construction activities to the manufacturing sector or outsourced to suppliers offshore has resulted in a construction sector that is responsible for a declining share of work. The tasks that remain firmly in the hands of the construction company are often the less productive assembly work on-site. Increasing market competition drives profit down to unsustainable levels, allowing productivity gains in the construction industry to be accrued to construction clients instead.

Traditional approaches to construction productivity that are based on final outputs are no longer useful. Given that construction tasks are now increasingly fragmented across companies and geographical borders, a new approach that measures

productivity in each stage of the construction process may be required. The OECD recently proposed a global value chain approach to identify the sources and to quantify the amount of gross flows and value added generated over the entire production chain (Marcolin *et al.,* 2016). Extending this approach to quantify the gross flows, value added, labour and capital inputs for the construction industry may provide a more accurate measure of productivities along this increasingly partitioned value chain. An approach that mirrors Timmer's (2017) global value chain productivity measure where all stages of production are analysed may be a potential solution. In the case of the construction industry, this value chain can be described as all the companies in the supply and manufacture of intermediate products. The contributions from both construction and non-construction sectors will be explicitly accounted for through the modelling of input-output linkages across sectors. Following the same logic, the number of workers that is directly and indirectly involved in the construction value chain, or the amount of capital, can be traced. Numerous practical challenges remain, not least the requirement to obtain data on the various sectors of the economy that is not normally classified as being part of the construction industry.

CONCLUSIONS

A review of existing measures of construction productivity indicates that two classes of measures exists: (i) physical productivity measures that indicate output per unit input such as square metres of building completed per man-hour, or linear meter of pipe laid per man-day, and (ii) productivity in dollar terms such as gross output per labour input or value added per labour input. Inconsistencies in the definition of productivity measures give rise to difficulties in comparing the productivity between tasks, firms and countries, and over time.

Research utilising physical measures indicates that labour productivity is increasing with the productivity growth being attributed to increased use of modern equipment and improvements in technology. These labour productivity measures are sensitive to price deflators that are computed using either wage or material price indices. While improved estimates of price deflators in recent studies has led to observations of increases in labour productivity, there is still considerable debate over the choice of approaches.

The construction production system has evolved from numerous trades working at a single location many decades ago to a multi-stage process involving many different suppliers, sub-contractors and trades in multiple locations and increasingly across geographical borders. This poses new challenges to the estimation of productivity of the construction industry through increasing intermediate inputs, offsite manufacturing, imports, offshoring and widespread use of labour and equipment hire practices. Measuring labour productivity in dollar terms is fraught with difficulties especially when examining the effects of changing production linkages across industries and countries. This review has found that tracking of prices and quantities of intermediate goods and services by sub-contractors and suppliers is especially difficult when combined with the effect of market forces that may limit the capture of the gains from productivity within the construction sector.

Clearly more research and debate are needed about how productivity should be measured. A global value chain approach has been proposed as a potential method of tracing the value added and productivities at every stage of production.

REFERENCES

Abdel-Wahab, M and Vogl, B (2011) Trends of productivity growth in the construction industry across Europe, US and Japan, *Construction Management and Economics*, 29(**6**), 635-644.

Allen, S G (1985) *Why Construction Industry Productivity is Declining*. NBER Working Papers 1555, National Bureau of Economic Research, Inc

Allmon, E, Haas, C T, Borcherding, J D and Goodrum, P M (2000) US construction labor productivity trends, 1970-1998, *Journal of Construction Engineering and Management*, 126(**2**), 97-104.

Australian Bureau of Statistics (ABS) (2016) *Australian System of National Accounts: Concepts, Sources and Methods*. Australian Bureau of Statistics

Baldwin, R (2016) *The Great Convergence: Information Technology and the New Globalization*. Belknap Press: An Imprint of Harvard University Press.

Barbosa, F, Woetzel, J, Mischke, J, Ribeirinho, M J, Sridhar, M, Parsons, M, Betram N and Brown, S (2017) *Reinventing Construction: A Route to Higher Productivity*. McKinsey Global Institute.

Bernstein, H M (2003) Measuring Productivity: An Industry problem, *Civil Engineering*, 46-53.

Building and Construction Authority (BCA) (2019) *Project Productivity*. Available from https://www.bca.gov.sg/Productivity/site_productivity_statistics.html [Accessed 07/01/2019].

Chancellor, W, Abbott M and Carson C (2019) Productivity and levels of output in the construction industry, *In*: R Best and J Meikle (Eds.) *Accounting for Construction: Frameworks, Productivity, Cost and Performance*. Abingdon: Routledge.

Construction, Forestry, Maritime, Mining and Energy Union (CFMEU) (2015) *Labour Hire and Insecure Work*, November 2015.

Crawford, P and Vogl, B (2006) Measuring productivity in the construction industry, *Building Research and Information*, 34(**3**), 208-219.

Forsythe, P (2018) Extending and operationalizing construction productivity measurement on building projects, *Construction Management and Economics*, 36(**12**), 683-699.

Green, B (2016) *Productivity in Construction: Creating a Framework for the Industry to Thrive*. Chartered Institute of Building.

Low, S P (2015) A review of construction productivity indicators in Singapore, *The Singapore Engineer*, August 2015, 24-30.

Marcolin, L, Miroudot, S and Squicciarini, M (2016) *Gvcs, Jobs and Routine Content of Occupations*. Organisation for Economic Co-operation and Development, Paris: OECD Trade Policy Papers.

OECD (2001) *Measuring Productivity - Measurement of Aggregate and Industry-Level Productivity Growth*, Organisation for Economic Co-operation and Development, Paris.

O'Mahony, M and Timmer, M P (2009) Output, input and productivity measures at the industry level: The EU KLEMS database, *The Economic Journal*, 119(**538**), F374-F403.

Productivity Commission (2014) *Public Infrastructure, Inquiry Report No 71*, Canberra, Australia.

Pan, W (2018) Rethinking construction productivity theory and practice, *Built Environment Project and Asset Management*, 8(**3**), 234-238.

Remes, J, Manyika, J, Bughin, J, Woetzel, J, Mischke, J and Krishnan, M (2018) *Solving the Productivity Puzzle: The Role of Demand and the Promise of Digitization*, McKinsey Global Institute.

Richardson, D (2014) *Productivity in the Construction Industry*, Australia Institute.

Robinson, J (2013) *The Accumulation of Capital*. Basingstoke: Palgrave Macmillan.

Rojas, E M and Aramvareekul, P (2003) Is construction labor productivity really declining? *Journal of Construction Engineering and Management*, 129(**1**), 41-46.

Ruddock, L and Ruddock, S (2011) Evaluation of trends in the UK construction industry using growth and productivity accounts, *Construction Management and Economics*, 29(**12**), 1229-1239.

Sveikauskas, L, Rowe, S, Mildenberger, J, Price, J and Young, A (2016) Productivity growth in construction, *Journal of Construction Engineering and Management*, 142(**10**), 04016045.

Tan, W (2000) Total factor productivity in Singapore construction, *Engineering, Construction and Architectural Management*, 7(**2**), 154-158.

Teicholz, P, Goodrum, P M and Haas, C T (2001) US construction labor productivity trends, 1970-1998, *Journal of Construction Engineering and Management*, 127(**5**), 427-429.

The Economist (2017) *The Construction Industry's Productivity Problem - Can We Fix It*? 17 August 2017.

Timmer, M (2017) *Productivity Measurement in Global Value Chains*, International Productivity Monitor, 33, 182-193.

Yi, W and Chan, A P (2013) Critical review of labor productivity research in construction journals, *Journal of Management in Engineering*, 30(**2**), 214-225.

ACADEMIA-INDUSTRY ENGAGEMENT

YOUNG SYRIAN ARCHITECTS (YSA) AT THE TIME OF CRISES

Ammar Azzouz[1] and Abeer Abdelal[2]

[1] *School of Geography and the Environment, University of Oxford, South Parks Road, OX1 3QY, UK*

[2] *Faculty of Architecture and Urban Planning, Al-Wataniya Private University (WPU), Hama, Syria*

The urban nature of the Syrian conflict has caused heavy physical damage to cities and displaced over half of the population. From those displaced, there are 6.5 million people internally displaced within Syria, occasionally for several times. The Syrian refugee crisis has attracted significant attention by media, researchers and policymakers, yet responses to crises inside Syria were not equally considered. This research paper addresses this gap and contributes to the knowledge of cities at war. It aims to understand the roles of architects at the time of war and focuses particularly on the possible ways to support them in their struggle to save their cities and protect their heritage. To do so, interviews were undertaken remotely from London, UK, with architects living in Homs, Syria; a city that has been radically reshaped by the mass destruction of its neighbourhoods. In addition, a workshop was organised with 25 architects in Homs to think of creative ideas for Syrian architects and international professionals in the built environment to help remotely from abroad. Findings show that there are several practical and highly needed projects that could be undertaken from distance to support architects in conflict zones e.g. providing online training courses, creating digital libraries in Arabic on conflict in cities, and establishing collaborative research projects between academics, architects and engineers outside and inside Syria. It is hoped that this research paper will influence academics, professionals and policy-makers to create tangible projects to support impacted communities in their struggle to sustain and reconstruct their cities and countryside. This is not only needed in Syria but could also be transformative to other countries as Iraq, Yemen and Libya.

Keywords: Architect, warzones, Homs, Syria, rebuilding, contested cities

INTRODUCTION

Cities at War; War at Cities

We live in an era of intensive destruction of cities and countryside. Wars entered cities and their urban settings with waves of heavy destruction of the built environment (Vale and Campanella, 2005). Cities have become the urban battlefield in many conflicts (Graham, 2012); as in Aleppo, Raqqa (Syria), Misrata (Libya), Gaza (Palestine), Mosul (Iraq) and Beirut (Lebanon). They were partially or completely besieged, contested, destroyed and divided; left in ruins for years of long-term ongoing conflicts. Ordinary civilians find themselves living in the midst of these conflicted cities, struggling in their everyday lives with new spatial and urban structures of fences, walls, checkpoints, besieged neighbourhoods, and non-functional

[1] ammar.azzouz@arup.com

Azzouz, A and Abdelal, A (2019) Young Syrian Architects (YSA) At the Time of Crises *In:* Gorse, C and Neilson, C J (Eds) *Proceedings of the 35th Annual ARCOM Conference,* 2-4 September 2019, Leeds, UK, Association of Researchers in Construction Management, 154-163.

areas (Piquard and Swenarton, 2011). Their everyday life is reshaped by the constantly shifting frontlines and changing dynamics of wars.

In war on cities, monumental architecture and cultural heritage sites are wilfully targeted for their meaning and significance (Grodach, 2002), and for their representation of the collective identity of civilisations (Viejo-Rose, 2014). Their destruction has been used as a cultural warfare for the collective memory these sites hold to their nations (Sørensen and Viejo-Rose, 2015). In recent decades, the damage caused to the ancient city of Nimrud in Iraq, Palmyra, the Ancient City of Aleppo, and Krak des Chevaliers in Syria, the destruction of Mostar's historic bridge in Bosnia and Herzegovina, the several houses and historic buildings in the Old City of Sana'a, the airstrikes on the ancient city of Maarib in Yemen, and the blowing up of Bamiyan Buddha's in Afghanistan, have all caused national and international outrage as these sites mirror the weight of history and the achievements of civilisations and ancestors who lived in these regions.

In urbicide, the deliberate destruction of the built environment (Abujidi, 2014; Coward, 2008; Graham, 2008), destruction does not only target and impact selective cultural heritage sites, but entire residential areas; causing internal and external displacement of local communities. Thus, the destruction in many wars is no longer focused on specific buildings between fighting groups, but entire neighbourhoods are heavily destroyed, and sometimes, razed to the ground. This deliberate destruction of home is referred to as domicide (Porteous and Smith, 2003), that causes deep suffering to its impacted people not only because of the physical loss of their homes, but also because of the values that home represents i.e. safety, sense of security and belonging (Boano, 2011).

In Syria, since 2011, the mass destruction and sheer levelling of cities and countryside, has made it essential for architects to shift their thinking in response to destruction and displacement. They face extreme emergency challenges; with limited resources, difficult everyday living conditions, shortage of building materials, and lack of economic opportunities (Azzouz, 2018). But despite these challenges, and with the start of the ninth year of crises, architects are showing incredible levels of resilience to rehabilitate their cities, map damage, and protect the monumental and everyday heritage of local communities (Azzouz, 2019). However, these efforts could be supported and strengthened remotely by academics, architects and engineers who live and work outside Syria. This paper, therefore, aims to understand the several mechanisms and strategies for diasporic communities and international organisations and universities to support architects in warzones. This research is highly needed and timely to think of communities who live in ruined cities as they struggle to provide shelter to Internally Displaced Persons (IDPs), to rebuild their desolated neighbourhoods, and to protect and sustain what remains of their cities and countryside. The main research question of this is: how could architects and professionals in the Architecture, Engineering and Construction (AEC) sector outside Syria provide support and collaborate with local communities and architects inside Syria remotely?

Violence Taking Place in Syria

For more than two millennia, architectural ruins and buried archaeological sites have been preserved in the Middle East reflecting the weight of history and the diverse civilisations that lived in the region. It is there in the Fertile Crescent that agriculture and urban societies were first established and flourished. Empires, military powers,

international traders and cultures have interfaced in the past resulting in the currently known 'Syria'.

However, the destruction of Syria since the beginning of the crises in 2011 until the present has radically reshaped the lives of millions of Syrians. Over half of the population has been displaced either internally or externally (10m), tens of thousands of lives have been lost and the country's glorious heritage and contemporary cities have been destructed (Figure 1).

Figure 1: Destruction of residential areas in Homs, Syria. Source: Majd Murad, 2018.

Whilst policy makers, researchers, professionals, aid organisations and politicians have directed significant interest towards the Syrian refugee and migrant crisis (Syrians displaced externally), less efforts have focused on the life of Syrians inside Syria - those who either had no choice to flee or decided to stay 'home' despite the violent conflict. Their presence reflects the resistance and resilience of these communities as their everyday life has been reshaped with extremely difficult life conditions. This research, therefore, explores this significant gap in knowledge by engaging with Syrians who are still inside Syria to bring the human agency to the struggle of Syrians at the time of war.

The research focuses on Homs, the third largest city in Syria, with around 800,000 inhabitants before 2011, and which half of it was heavily damaged in the last eight years (other 25% of the city is partially damaged). Homs is the city of the first author and is also where the second author currently resides and lectures. Many of the current research projects and emerging debates on Syria fail to engage with impacted Syrian community; which in turn lead to a lack of representation of Syrian voices raising questions about ethics and morals of emerging research projects. Some of these projects are even ran by researchers who do not speak the language or have no past experience on Syria - see more on this in (Sukarieh and Tannock, 2019). The research addressed in this paper contrasts with past and current studies. It creates a

dialogue and a conversation with hard-to-reach participants who still reside in Syria and attempts to understand the real needs and wants of architects in warzones instead of imposing pre-determined solutions and projects as done by many international NGOs who impose their own agendas that - in several cases - do not mirror what local communities need.

Architects in Syria: Before 2011

Before 2011, the architecture profession was associated with the Syrian Engineering Institute. All architects had to be members of the institute prior to being able to work independently. This is the same for all other engineering disciplines (civil, mechanical and structural for instance). Before the 20th century, city development was based on craftsmen, skilful builders and locals. Building legislations were formed mostly by religious directions and environmental aspects. With the beginning of the 20th century, and at the time of French mandate and its cultural and political impact; new architectural and urban styles were adopted by trained architects. After the end of the French Mandate in Syria, there has been an urban growth in cities, and there was a need to respond to that growth from architects and planners. All architects had to work for at least five years in one of the state's institutions before being able to open their private architectural practices. At the beginning, this was seen as an opportunity for architects to get practical experiences to understand the regulations and standards and to prepare architects themselves and to work independently in their own future practices.

However, with the increasing numbers of architecture graduates and the decreasing numbers of new public projects, these regulations changed accordingly; engineers had been exempted from this obligation in 1996, so that young architects can work independently. This has led to the emergence of new private architecture practices in the city that started to design and imagine several projects in Homs and these young architects were able to contribute to these projects. But even with this level of independence, rigid and inflexible building regulations made many of these young architects unable to express their ideas creatively; which impacted on the city and its identity. At the time, many young architects saw in the Western cities a source to import ideas and copy them in Homs (sometimes also influenced by hybrid architectural styles in Saudi Arabia, Kuwait and UAE). These influences led to the emergence of different architectural styles that do not mirror the life and culture of Homs.

Additionally, there was a gap between the architectural education at the university level and what architects had to do in practice. Many students worked on imaginary sites not on real sites and cases within the city, leading to ignorance of real challenges and surroundings. However, in the first decade of the twenty first century, the city was the site of new emerging ideas that proposed radical regeneration visions; these ideas were put together in a project called 'The Homs Dream'. This project relied on selecting strategic sites in the city that had importance in terms of location and significance. The main goal of this large-scale project was to increase investment activities by transforming these sites into investment and multi-functional projects. The proposal employed modern architectural styles, and suggested demolishing existing buildings at the heart of the city and replacing them with high-rise towers with over twenty-five floors in a city where the few high buildings were no more than ten floors. Despite the promises that were proposed, the project was heavily criticised by most of the Homsis as it was far from the real needs of people in the city. The

project was not an outcome of a city strategy that aims to improve the life conditions in the city, but rather it focused on specific sites at the City Centre. It was also seen as the construction of destruction as it aimed to destroy the familiar and change the social and cultural fabrics of the city. No consultation with local communities was undertaken and as a result, residents including owners and shopkeepers called for the project to stop. The 'Homs Dream' has never seen the light, and soon after its proposal, the crises started and reshaped the city.

Rebuilding and Thinking about Reconstruction Start at the Time of War

The long-term war in Syria has made it essential for architects, engineers, urban planners and academics to shift their thinking in their struggle to protect their local heritage, to sustain their countryside and cities, and to think about the future reconstruction of the country. During the days of heavy shelling local architects and photographers were among the first people who started collecting photos of all threatened buildings, squares, corners all over the city. Many local residents joined this wave of documentation and as a result, new platforms on social media started presenting how the city is being transformed by the crises with the destruction of its built environment. Architects, just like all residents, participated in efforts to help displaced families who were hosted in schools or in other shared shelters after they left their troubled neighbourhoods. They no longer waited for 'post-war reconstruction' plans or 'peace resolutions' to rethink their role at the time of war, and to discuss the future rebuilding of their country. Rather, they worked on different levels to deal with rebuilding their ruined built environment, to provide shelter for the IDPs and to analyse and categorise levels of destruction damage in cities and countryside.

Local Non-Governmental Organisations (NGOs) and charities play a significant role in supporting devastated communities. Some charities might have existed before conflicts but evolve remarkably both in scale and missions throughout the years of war. Others emerge during the conflict to respond to the emergency needs of communities. In Homs, for instance, Jamiat Al-bir wa Al-Khadamat Al-Ejtemaeia (the Charity of Righteousness and Social Services) was found in 1956. However, since 2011, the charity's work has evolved and expanded enormously. New themes and projects have been created as emergency responses to the crises, and later, as long-term projects for the city's early recovery. Today, the charity has 750 staff and 1000 volunteers of local people. Throughout the conflict years, architects work for the charity has reached thousands of people focusing both on the tangible and intangible aspects of city recovery on different projects that include the rehabilitation of partially damaged apartments to enable IDPs return to their homes.

Beyond local NGOs and charities, international organisations provide different forms of assistance to support local communities preserving their built environment. However, this support is influenced by the level of engagement these organisations can offer, depending on whether they can function on the ground or not. In Syria, there are already several United Nations (UN) agencies working on the ground with local teams of architects and other specialities; whilst other international organisations decided not to enter the Syrian borders or fund any project inside Syria.

Syrian diasporas are also initiating new projects to think about the destruction and reconstruction of cities and towns in Syria. There are several attempts to map pre-war memories and to understand how this could influence the future of Syria; others are undertaking research projects on the reconstruction of Syria, not only from a tangible

perspective, but also from cultural and social perspectives. These efforts have also been supplemented by new emerging writings on urban issues related to rebuilding communities and reconstruction including themes such as land ownership, and conservation of architecture and cultural heritage. They are also keen to support their fellow architects who still reside in Syria, but there is an urgent need to know what the needs and mechanisms are to provide this support; which this research aims to explore.

RESEARCH METHOD

This research focuses on Homs City where 18 (50%) of the city's neighbourhoods were heavily damaged, and other 8 (22%) were partially damaged, whilst 10 (28%) neighbourhoods have minor to no damage but yet affected by the crises; according to a report in 2014 (UN-Habitat, 2014). Parts of the city were besieged during the war, and with the large-scale destruction of its built environment, the city is today divided by still standing areas and other ruined and empty abandoned areas. Throughout the years of war, the city was partially besieged multiple times with urban frontier of checkpoints, walls and fences. Now after eight years of conflict, debates on reconstruction of Syria have already emerged, but many of them have focused on the most famous and internationally well-known locations, such as the Ancient City of Aleppo, with lack of discussions on Homs, and other cities as Raqqa and Deir ez-Zor.

Engaging with Local Architects Inside Syria

There has been an increasing interest in building awareness about the Syrian crises internationally. This has been covered via different platforms; from museums and art galleries, to universities and think-tank institutions. Several talks, events, conferences and seminars have been organised sine 2011 on different themes related to Syria. However, many of these efforts have failed to represent the Syrian voices and some have even failed to engage with impacted communities (even with Syrian diaspora, or remotely with Syrians inside Syria). There have been some panel discussions on Syria in top universities in the UK without a single Syrian on the panel. This research contrasts with these efforts as it humanises and individualises the Syrian crises by engaging with young architects who still reside in Homs.

This research builds on remote engagement with architects as both authors were outside Syria at the time of the research. The City of Homs, as other cities and towns in Syria, was the battlefield were the fights were carried out in its streets for several years. Architects, as other residents and professions in the city, have been kidnapped, displaced, threatened, and besieged. Many of them had to shift their thinking at the time of war, and to work in other disciplines. Today, there is a need for an international solidarity to support and collaborate with architects in contentious cities, even without being physically with them. This was the main motivation for undertaking this research and the reasons behind choosing this research method.

The research in this paper focuses on young architects for several reasons. First, these young architects are incredibly open to exploring new ideas, new ways of learning and research collaborations. They are advancing in the use of technology and keen to create a dialogue with audiences outside Syria for research and knowledge exchange. Secondly, young architects were at the forefront when local charities and NGOs emerged at the time of crises. They were heavily engaged and remarkably passionate to protect their city and communities. Together with young architects, a workshop and a conversation were organised remotely by the first author and the young

architects. These architects gathered together in Homs in an organisation called: Development, Organisations, Opportunity, Research and Services (DOORS) that is trying to create a network of architects to respond to the challenges facing their city and to think about the future of their country. The organisation has a network of 125 professionals in Homs from different backgrounds (e.g. IT, mechanical, electrical and civil engineers). However, one of DOORS' teams focuses solely on architecture which includes 25 architects; and the workshop was carried out with them. This group includes young architecture graduates and final year architecture students (architecture degree is five years in Syria).

Conversation with Local Architects in Syria

Under difficult living and working conditions still faced in Homs, the young architects joined the event in December 2017. The discussions initially focused on the role of architects at the time of conflict and offered brief insights on the ways the built environment in ruined cities can either help to unite or further divide societies (Yassin, 2008). This included examples where the ruins of wars were preserved to remember the times of conflicts, as in Coventry Cathedral in the UK and the remains of the Berlin Wall in Germany; and the importance of memory when the past is being erased, and how could this memory influence and shape the future of contested cities. Attention was then directed towards exploring how to help architects in warzones remotely by diasporic communities and international academics and organisations who are interested in providing distance support.

In an exercise organised by the first author, young architects were asked to create a list of undertakings they think Syrian diaspora and international researchers, professionals and academics can help with from distance. These topics also reflect on the special interests of the architectural team and the work they would like to practically address in their organisation. They divided themselves into three small groups, and later each group presented their ideas. Findings of two of the three groups are presented in the following.

Group A:

- Academic and educational support: There is a need to create online programmes that focus on different aspects of the built environment. These programmes could be supplemented with lectures where academics and researchers can review the young architect's work and provide the appropriate help.
- Connect with international researchers: If architects inside and outside Syria are connected, then this connection would be helpful to be up-to-date about the emerging debates in the built environment, and hopefully, it will lead young architects in Syria to be part of emerging research projects.
- Create online courses on project management and construction.
- The need to transfer knowledge for young architects from English to Arabic: Resources and educational materials can be more effective and impactful if they are in Arabic, so more people can benefit from. Syrian diaspora (and other Arabic speaking architects and researchers) could potentially help with this and support channels of knowledge exchange.
- Create opportunities for training outside Syria: There are many conferences and training programmes on Syria taking place in different countries. It would be helpful to be able to attend and participate in these events.

- Need to create better mechanisms and channels to exchange knowledge and educational materials from and to Syrians inside Syria.

Group B:

- Online workshops: The need to create and share knowledge on architecture, construction and engineering through online workshops and learning courses.
- Research collaborations with universities outside Syria: This would be important to develop research skills and conduct new and original research on a Syrian city at war, which is needed in the emerging debates on reconstruction of Syrian cities.
- Establish platforms to support the construction and structural projects in Homs, through online project review that enable live feedback and help.
- Provide support to access research articles as young architects and students do not have access to materials through university accounts.
- The need for more examples on reconstruction of cities that went through conflicts with more details about the different matters surrounding the reconstruction of these cities.
- The need for case study projects in real situations and the different stages of the project life-cycle (from brief and concept design, to construction, hand over and in use). Particularly, it would be helpful to have projects cases where they have been built in emergency situations and after wars and disasters.
- Develop a shared online library, where recourses could put all together; including: Learning materials, online courses, educational tools and project case studies.

From Research to Practice

As seen in these two groups, there are areas of overlap, and young architects highlight the need for educational channels to transfer experiences, skills, information and knowledge from and to Syria. Each of the ideas suggested at the workshop could be transformed into a project to support and help architects in warzones, but there is a need for collaboration between local and international academics and AEC professionals to create programmes that support architects in warzones in their struggle to save and sustain their cities and communities. All the three groups emphasised on the need for them to access new knowledge on cities and wars to learn from other scenarios and explore how cities rise again after destruction. They acknowledge the potentiality of digital platforms to collaborate, create dialogues and access research and knowledge.

There are many opportunities and potentialities to help architects inside Syria and in other contested regions. This help could be provided by academics and professionals in the AEC sector outside Syria, and at the same time, Syrian academics and architects can provide knowledge and experiences on what is happening on the ground in Syria, and how communities carried out in their everyday life at the time of destruction and desolation of cities. There is an urgent need for international solidarity and for academics and professionals outside Syria to think about their role and responsibilities in providing support and help to communities in ruined cities.

With the displacement and or killing of many architects outside Syria, and the lack of research and access to academic papers, the academic and educational levels have been heavily affected. At the university in Homs, the staff in Urban Planning division decreased from 20 before 2011 to only 3 now. Therefore, many students and

architects inside Syria emphasise on the need to catch up with new knowledge and materials that are impacting the built environment.

There is a need for academic and professional materials in Arabic on different cities that went through conflict. Translations of previous research papers and policy repots could contribute to the knowledge of destruction and reconstruction of cities in Arabic. Translated Arabic resources and the creation of digital library could focus on different aspects related to war on cities including sharing space in divided cities, the politics of reconstruction, heritage and the everyday life in contested cities, the possible ways architects and planners can engage with local communities to shape the future of their built environment, and the role of architecture in providing a sense of social cohesion and unity in war-torn cities. Such translations are helpful to architects, engineers, urban planners, NGOs and local communities, not only in Syria, but also in other Middle Eastern countries such as Palestine, Iraq, Yemen and Libya.

CONCLUSION

At the time of destruction and erasure of the past; architects rediscover and re-examine their role in response to the destruction of the built environment and displacement of local communities. They explore how their profession contribute directly to alleviate social, economic and environmental crises impact that has been compounded tremendously by the disasters of war. Syrian architects have also discovered how participatory architecture can enrich their thoughts instead of working solely without engaging with residents (as in the case of the 'Homs Dream'). They are fully aware of academic shortages in their educational institutions caused by war time and seek new platforms of learning. They are also working on building bridges with diasporic communities and international organisations and architects at the time of crises to exchange knowledge and establish learning and collaboration projects.

This paper has shown several creative ideas suggested by a group of Syrian young architects who still reside in Homs. It shows a wide range of opportunities for international architects, engineers, organisations, academics and researchers to support and collaborate with architects in war-zones. These ideas should be examined and translated into tangible projects that strengthen the work of local architects who live in contested environments, enable them to protect what remains of their cities and to put the old and new pieces of their built environment together again. It is hoped that the research in this paper will influence academics and professionals to rethink who are the communities that need help, and to consider the challenges facing communities in destructed cities such as Homs.

REFERENCES

Abujidi, N (2014) *Urbicide in Palestine: Spaces of Oppression and Resilience*. Abingdon, UK: Routledge.

Azzouz, A (2018) *How Syrian Architects Can Rebuild a Country in the Throes of War*, The Independent, Available from https://www.independent.co.uk/life-style/design/syria-civil-war-architecture-rebuilding-cities-design-a8599311.html

Azzouz, A (2019) A tale of a Syrian city at war: Destruction, resilience and memory in Homs, *City*, 23(**1**).

Boano, C (2011) Violent spaces: Production and reproduction of security and vulnerabilities, *Journal of Architecture*, 16(**1**), 37-55.

Coward, M (2008) *Urbicide: the Politics of Urban Destruction*. Abingdon: Routledge.

Graham, S (2008) Constructing Urbicide by Bulldozer in the Occupied Territories In Cities, War and Terrorism: Towards an Urban Geopolitics, Chichester, Wiley.

Graham, S (2012) *Cities Under Siege: the New Military Urbanism*. London: Verso.

Grodach, C (2002) Reconstituting identity and history in post-war Mostar, Bosnia-Herzegovina, *City*, 6(**1**), 61-82.

Piquard, B and Swenarton, M (2011) Learning from architecture and conflict, *Journal of Architecture*, 16(**1**), 1-13.

Porteous, J D and Smith, S E (2003) Domicide: The global destruction of home, *Housing Studies*, 18(**2**), 269-272.

Sørensen, M L S and Viejo-Rose, D (2015) *War and Cultural Heritage: Biographies of Place*. Cambridge: Cambridge University Press.

Sukarieh, M and Tannock, S (2019) Subcontracting academia: Alienation, exploitation and disillusionment in the uk overseas syrian refugee research industry, *Antipode*, 51(**2**).

UN-Habitat (2014) *City Profile Homs: Multi Sector Assessment*. United Nations: Habitat.

Vale, L J and Campanella, T J (2005) *The Resilient City : How Modern Cities Recover from Disasters*. Oxford: Oxford University Press.

Viejo-Rose, D (2014) *Reconstructing Spain Cultural Heritage and Memory After Civil War*, London: Sussex Academic Press

Yassin, N (2008) Can urbanism heal the scars of conflict? *City*, 12(**3**), 398-401.

ENHANCING ASSESSMENT TO PREPARE UNDERGRADUATES AS EFFECTIVE BUILT ENVIRONMENT INDUSTRY PRACTITIONERS

Barbara Vohmann[1]

Engineering and the Built Environment, Anglia Ruskin University, Chelmsford Campus, Bishop Hall Lane, Chelmsford, Essex CM1 1SQ, UK

Meeting the needs of industry is one function of higher education and preparing students for employment in industry is a central goal of professionally recognised undergraduate built environment courses. Assessment is a key influence on the learning activities students undertake. Designing assessment to be authentic to professional practice can support students' preparation and development for industry through the simulation of real-world experiences. There is a considerable amount of literature regarding authentic assessment, yet most literature in this field does not specifically address the needs of construction undergraduates. To evaluate the efficacy of authentic assessment to support students learning and preparation for industry, an action research project was undertaken in a UK university. This paper reports part of that project, where an assessment brief was modified to enhance authenticity in a practice-based subject. Following this modification to assessment design, data concerning students' perception of the modified assessment was gathered from a focus group of students. Findings suggest that the authentic assessment was perceived by students as an improved experience which better supported their development of real-world knowledge and skills.

Keywords: Assessment, education, employability, learning, professionalism

INTRODUCTION

Providing skilled graduates as effective industry practitioners and thereby contributing to a healthy economy is one important function of higher education (Leitch 2006). Knowledge and skills developed in higher education help graduates to make an important contribution to creating such a healthy economy (Smith *et al.,* 2012). The current economic and political environment means that effective higher education is all the more significant to help the UK maintain its global competitiveness. However, literature identifies that across the higher education sector, built environment students often lack adequate practice-based competencies and that graduates' skills often fall short of employers' expectations (Quarterman 2017). The Chartered Institute of Building reported that 34% of construction employers considered graduates did not have appropriate skills for industry (Rawlins and Marasini 2011). Further, there was some concern that traditional approaches to teaching meant that built environment graduates were not adequately prepared with appropriate employability skills (Chan and Sher 2014). By 2019, there was also concern surrounding a shortage in a number of construction occupations, including professional areas, and in many instances, this

[1] barbara.vohmann@anglia.ac.uk

Vohmann, B (2019) Enhancing Assessment to Prepare Undergraduates as Effective Built Environment Industry Practitioners *In:* Gorse, C and Neilson, C J (Eds) *Proceedings of the 35th Annual ARCOM Conference,* 2-4 September 2019, Leeds, UK, Association of Researchers in Construction Management, 164-173.

was anticipated to be a position which could deteriorate following the UKs departure from the European Union (CIOB 2019). Together, these highlight the need to ensure that construction graduates are able to respond to the challenges facing industry; in short, that they are developed as effective industry practitioners.

Developing students' employability skills as well as developing their industry specific knowledge and skills is recognised as an important dimension of higher education, and professional bodies play an important role in helping institutions maintain the currency and relevance of their courses for the benefit of industry and the economy (Green 2015). In short, enhancing graduates work-readiness would help to meet employers' needs more effectively, preparing students for industry as effective practitioners. This paper reports part of a doctoral study which examines the use of authentic assessment in order to provide an enhanced learning experience, helping to better prepare students as industry practitioners.

Assessment is arguably the most important part of the undergraduate learning experience and is the focus of students' learning activities in formal learning environments (Bodman 2007). This is important because assessment should, in addition to developing students' theoretical knowledge, contribute to their preparation for employment in industry as effective practitioners.

The well-established courses at the Higher Education Institution in this research incorporate five built environment disciplines, including construction management. It must be noted that students on these courses have expressed, through the National Student Survey, a high degree of satisfaction with the learning experience provided. All built environment courses at this institution retain their accreditation and employers continue to support their employees to undertake those courses. This suggests that the courses continue to meet the demands of students, professional bodies and employers.

The aim of this paper is to examine students' perceptions of assessment in built environment courses to establish whether they evaluate assessment modified to enhance authenticity as better meeting their learning needs. Objectives of this paper are as follows. First, through a literature review to explore the central issues pertaining to learning, authentic assessment, and, employability. Second, to modify assessment design then gather and analyse data regarding student evaluations of their learning experience in respect of the modified assessment.

THEORETICAL PERSPECTIVES

Learning and skills development

Learning is when people can demonstrate something they could not previously do or did not know (Honey and Mumford 1992). To be effective, high quality 'deep' learning should be undertaken (Eastcott and Farmer 1995). Deep learning involves the learner understanding a subject rather than merely reproducing portions of it (Baek and Lee 2012), interacting with the subject (Cotton 1995), and the learner researching for themselves (Biggs and Telfer 1987). This suggests that assessment, should be designed to stimulate deep learning; on professionally focused courses, this includes learning of practice-based knowledge in addition to theory.

Formal learning occurs in an educational institution and non-formal learning occurs in the workplace (Rubenson 2010). For undergraduates in professionally focused courses, formal learning should connect with the demands of the workplace thereby helping to prepare students as practitioners. In other words, formal and non-formal

learning should be clearly connected. However, formal learning undertaken in higher education and the learning necessary for effectiveness in professional practice can sometimes be different. Consequently, this creates challenges for students as they attempt to understand and link these two disparate entities (Joseph and Juwah 2012).

Knowledge acquired through formal learning can be categorised in Bloom's taxonomy of educational objectives, which is composed of behaviours in "three domains - the cognitive, the psychomotor, and the affective" (Bloom 1956: 19). These domains are important because they identify the areas of knowledge and skill development which are relevant to academic study and which are also reflected in the demands placed on practitioners in the workplace. However, it is possible that assessment in formal learning environments focuses in particular on the cognitive domain, requiring students to undertake activities to demonstrate their theoretically-based knowledge, which would consequently diminish the practitioner-based aspect of assessment.

Authentic assessment

Assessment is often concerned with measuring attainment and providing a means to formally acknowledge what an individual has learnt in a specific area (Carter 2012). Authentic assessment, while having no generally agreed definition (Whitelock and Cross 2011), embraces assessment activities and resources which are relevant to the real world (Bosco and Ferns 2014), and which may require students to undertake real-world activities and develop knowledge and attitudes necessary in the workplace (Carter *et al.,* 2015). Authentic assessment may be regarded as being on a continuum from replicating or simulating practice-based activities to assessment which requires engagement with the real world but does not require the student to undertake real world activities. A key driver for this continuum is the nature of each subject under consideration. For example, some theoretically-based subjects on built environment courses provide appropriate knowledge for practitioners and which have application in industry, but which do not form the basis of activities that practitioners would normally undertake.

Given that assessment forms the focus of students learning activities, authentic assessment can offer scope to enhance students' preparedness for industry, presenting students with real world learning challenges and activities. Such challenges would offer scope for students to develop their attributes in each of Bloom's domains. Arguably, assessment which is authentic may also stimulate students to undertake deep learning as they recognise the application and value of such knowledge in industry. However, a challenge in built environment courses is that industry activities are often, at best, difficult to re-create with a high degree of authenticity. Finding routes to enhance authenticity could offer a route to augment students' preparedness for industry by engaging them with challenges and resources encountered and used by practitioners and which contain challenges the real world presents.

Employability

The role of higher education in contributing to development of student's employability skills has been widely recognised, including by the European Commission (European Commission/EACEA/Eurydice 2014). Built environment courses prepare undergraduates for industry, and this includes employability skills as well as industry specific technical and theoretical knowledge.

There is no widely agreed definition of employability, but a useful description is in that in addition to knowledge, employability skills include personal qualities and

being able to critically reflect on experience (Ornellas, Falkner and Edman Stalbrandt 2019), and these skills are recognised as valuable for industry (Knight and Yorke 2003). The Confederation of British Industry and the National Union of Students identify employability skills as communication, team working, problem solving, application of IT, self-management, customer awareness, application of numeracy, and having positive attitude (CBI/NUS 2011). Unfortunately, it is known that employers often consider undergraduates' employability skills as limited (CBI 2012). This suggests that enhancing the learning experience would be beneficial in order to develop those skills. Employability skills are important if students are to be able to function as effective industry practitioners and are a complement to technical industry-based knowledge which graduates should possess.

Developing employability skills "derives from the ways in which the student learns from his or her experiences" (Yorke 2006: 7). This is an important point, because it identifies the contribution that experience makes to development of employability skills and so highlights the value of authentic assessment as providing relevant learning experience. Given the significant role of assessment in learning, then it is clear that assessment can contribute to development of employability skills as well as development of students' theoretical knowledge.

METHOD

This work was undertaken as part of an action research project conducted at a post-1992 university. Such institutions have a long history of delivering practice-based courses (Aldhous 1991), which makes the study all the more relevant. The goal of this project was to implement and evaluate modifications to assessment design in built environment courses, seeking to enhance the learning experience through increased authenticity of assessment. The greatest challenge facing the researcher was to encourage tutors to enhance the degree of authenticity in the design of assessed coursework. This was addressed through two meetings of tutors to discuss issues including assessment design, two staff development days which considered assessment, and, informal verbal discussions.

As at most higher education institutions, courses in this study are composed of modules, which are a means of dividing courses into separate units of learning and assessing students in each of these units (Rodeiro and Nádas 2010). Assessment in a built environment practice-based module was modified during the academic year 2016/17 with the goal of increasing the degree of authenticity in order to enhance the student learning experience. It must be noted that the decision to change assessment in this particular module arose from earlier work of the doctoral study. This paper reports findings following this modification.

The module was studied by 35 students. Previously, assessment in the module had required students to make a group presentation to their tutors and with several weeks to prepare. For the action research of this study, assessment was modified to require students to give a group presentation to an industry practitioner as well as their tutors, the brief for which was provided on the morning of the presentation. These modifications to the brief were designed to bring about an increased degree of real-world authenticity. Also increasing the real-world authenticity was that students would have to make their presentation to a practitioner, and, having to produce the work in one day meant the deadline was short. It must be noted that in the preceding weeks students spent time with their tutor studying and reflecting on the subject matter, although the brief was not provided until the morning of the assessed

presentation. This meant that students had limited time to prepare, which simulated something of the challenges facing practitioners, where time is often in short supply. Arguably, these modifications to the assessment were small. However, their consequence for assessment was perceived by students as significant, making the assessment more challenging and relevant.

Following this change to assessment, there was a follow-up focus group of eight students to evaluate students' perceptions of the modifications. The focus group was composed of students who had studied the module and completed the modified assessment and was drawn from all students in the class. Students who participated were all volunteers, meaning that the sample was one of convenience (Gray 2014) and participants were self-selecting.

Ethical approval to undertake the research was secured prior to modifying assessment and the institutional ethics protocol was adhered to throughout the research. At the start of the focus group, each participant was provided with an information sheet explaining the purpose of the focus group. There was then an opportunity to clarify any areas of uncertainty and the opportunity for participants to decide whether or not to proceed. Participants also were offered the opportunity to check the transcription of the focus group and interpretation of the data if they so wished. To help put participants at their ease, the researcher explained that their contribution to the research by sharing their own views was vitally important as they were the experts not the researcher. It was also explained to participants that only a small amount of illustrative comments would be published and consequently would not be possible to identify any individual. Each participant, prior to the commencement of the focus group discussion, signed the institutional ethics paperwork as part of the required institution protocol. These completed forms were returned to the researcher and stored securely as required by the institution.

The researcher had a short list of written questions which were asked of the group to provide a framework for the discussion. Discussion in the focus group was recorded, transcribed, and checked several times for accuracy and was then subject to thematic analysis. Reasons for selecting thematic analysis were that it allows patterns to emerge from data (Braun and Clarke 2006), themes that coalesce around central ideas and meanings contained in the data (Gray 2014) could be identified and allow the researcher to understand participants experiences (Christensen and Probst 2015).

It should be noted that research such as this, with qualitative data, cannot with confidence be generalised to a wider context (Newman and Benz 1998). This project was intended to explore the issues within a single setting, and so generalisability was not a goal. However, it is expected it will be possible to make a "fuzzy generalization" (Bassey 1999: 12) and that the research should be of interest to tutors on similar courses at comparable institutions.

FINDINGS AND DISCUSSION

Focus group data revealed an interesting picture and a number of themes relating to development of real-world skills were identified: Assessment was perceived as providing higher level challenges; team-working was developed; and, working under the small-time constraint proved challenging. Despite this, students valued this modified assessment with its enhanced authenticity. Authentic assessment challenged students in each of Bloom's domains.

Students valued use of a real situation which involved engaging with practitioner during their assessment, and which they perceived made the assessment 'a big deal'. They also recognised that the assessment required them to behave more like practitioners, to 'think very quickly'. Authentic assessment was perceived as more challenging but part-time students, with industry experience, noted that 'you've got to do stuff like that'. They recognised that the higher degree of challenge was related to the practice-based authentic element of the task.

In this module, following the introduction of authentic assessment, students recognised the need for and value of teamwork: 'you've got to work as a team' and they had to 'help [team members] out if they struggled'. This was an interesting point because teamwork was embedded in course design, yet this was the only instance in the doctoral study where students alluded to it. They recognised that teamwork involved mutual support for other members which they had to provide in order to enhance overall group performance. In other words, they implicitly understood their team as a mutually supportive group striving to achieve a common goal.

The students also recognised that time was a constraint within which they would have to operate as practitioners, and which was incorporated into the assessment: 'we had limited time to prepare'. There was a perception that the limited time increased the degree of challenge they faced. This additional challenge reflected the real world, as practitioners often have to work to tight deadlines, and the authentic assessment emphasised this point to students.

In summary, students perceived authentic assessment as an enhanced experience which helped their learning and development for professional practice through providing real world challenges which reflected the demands placed on practitioners. Authentic assessment allowed students to develop their practice-based skills, albeit in an academic environment, and to experience something of the day-to-day challenges encountered by practitioners. This is similar to Wu, Heng and Wang (2015), who also found that students reported that authentic assessment enhanced their learning experience.

Students evaluated assessment more favourably than previously and the work as being interesting and relevant, and giving a learning experience which gave insight into practitioners' day-to-day work and to the real world. Arguably, if students perceive their assessment activities as professionally relevant then this would be more likely to encourage them to take a deep approach to learning as well as supporting development of their practice-based knowledge and skills and understanding of theoretical knowledge. James and Casidy (2018) also found that authentic assessment was linked positively with student satisfaction. Swanson (2011) found that students profit from real world practice-based activities which can provide an enhanced learning experience for students. These each highlight the 'added value' that the real-world activities of authentic assessment provide.

Challenges of the modified assessment were perceived by students as requiring them to act as practitioners under conditions which simulated aspects of the real world. This meant that they developed not only the skills required in industry, but importantly, the ability to use those skills under challenging conditions which simulated the real world so far as practicable. Helping students to develop as practitioners better meets the needs of industry, providing graduates who have experienced real world challenges and so the opportunity to develop their skills in response to those challenges. This is an important finding and identifies the role that

assessment plays in contributing to students' preparation for industry as effective practitioners. This is similar to Teagle *et al.,* (2017), who found that authentic assessment was evaluated positively by students and considered an effective learning experience in respect of preparing them for professional practice, which is the goal of accredited courses. Built environment graduates often lack adequate competency development and also readiness for professional practice (Witt *et al.,* 2013). Findings here suggest that the use of authentic assessment helps students to experience something of the challenges of the real world, and so supports their development as effective industry practitioners.

Students valued assessment which had immediate and direct application in the workplace; authentic assessment provided experience of such activities as well as supporting students' academic development. The importance and challenges of developing students' employability skills in preparation for industry has been recognised (Olawale 2015). This work suggests that using authentic assessment to develop such attributes provides an enhanced learning experience and helps prepare students for industry through undertaking activities which simulate the real world.

Authentic assessment encouraged students to take a deep approach to their learning. Authentic assessment has been found elsewhere to increase students' engagement and enhance their motivation (Davison 2011). This was evident in the application of knowledge and linking of theory with real world activities, which students perceived as more challenging and interesting. This is similar to Adapa (2015), who also found that authentic assessment facilitates deeper engagement with the subject. This suggests that authentic assessment encourages a deep approach to learning by providing clear relevance to professional practice. For built environment students, such relevance was an important contributor to their engagement with the assessment and potentially undertaking a deeper approach to their learning. As assessment is central in formal learning, so this use of authentic assessment provides a virtuous circle - supporting learning, helping students to take a deep approach and preparing them for industry by enhancing engagement with the real world through undertaking activities of practitioners. Assessment is the focus of students learning activities (Boud and Falchikov 2007) and assessment is a prevailing driver of the learning activities which students undertake (Deneen and Boud 2014). Together with evidence from this research, this highlights the value of assessment in built environment courses to embed authenticity which enables students to experience something of the challenges of the real world and so contributes to their preparation as practitioners.

CONCLUSIONS

A central role of higher education is to provide graduates who are able to meet the needs of industry using the knowledge and skills they have developed. Professionally recognised courses have a vital role to play, providing industry with graduates who have developed appropriate attributes to meet the demands placed on practitioners. Findings of this study suggest that student learning may be enhanced through the use of authentic assessment, that students expressed a preference for authentic assessment, and, that they perceived it as being helpful for their own personal professional development.

It is recognised that this research has been carried out in one place and over one time period, and indeed this was a goal of the main study which was seeking to address a specific problem. Nevertheless, this paper highlights the value of authentic

assessment for built environment students' professional development and their preparation for employment as more effective industry practitioners.

REFERENCES

Adapa, S (2015) Authentic assessment tasks: students take a deep approach to learning. *eLearn*, 5(**1**).

Aldhous, P (1991) University / polytechnic distinction to end. *Nature*, 351(6324), 257.

Baek, E-O and Lee, H-J (2012) Facilitating deep learning in a learning community. *International Journal of Technology and Human Interaction*, 8(**1**), 1-13.

Bassey, M (1999) *Case Study Research in Educational Settings*. Buckingham, UK: Open University Press.

Biggs, J and Telfer, R (1987) *The Process of Learning 2nd Edition*. Australia: Prentice-Hall.

Bloom, B S (1956) *Taxonomy of Educational Objectives. The Classification of Educational Goals. Handbook I: Cognitive Domain*. London: Longman Group Ltd.

Bodman, S (2007) *The Power of Feedback in Professional Learning*. EdD Thesis, Institute of Education, University of London.

Bosco, A M and Ferns, S (2014) Embedding of authentic assessment in work-integrated learning curriculum. *Asia-Pacific Journal of Cooperative Education*, 5(**4**), 281-290.

Boud, D and Falchikov, N (Eds.) (2007) *Rethinking Assessment in Higher Education: Learning for the Longer Term*. London: Routledge.

Braun, V and Clarke, V (2006) Using thematic analysis in psychology, *Qualitative Research in Psychology*, 3(**2**), 77-101.

Carter, A (2012) *Assessment in Action: A Study of Lecturers' and Students' Constructions of BTEC National Assessment Practice in a College Engineering Programme Area*. ProfD Education Thesis, University of the West of England.

Carter, A G, Sidebotham, M, Creedy, D K, Fenwick, J and Gamble, J (2015) Strengthening partnerships: The involvement of health care providers in the evaluation of authentic assessment within midwifery undergraduate education. *Nurse Education in Practice*, 15(**4**), 327-332.

CBI (2012) *Learning to Grow: What Employers Need from Education and Skills. Education and Skills Survey 2012*. London: CBI.

CBI/NUS (2011) *Working Towards Your Future. Making the Most of Your Time in Higher Education*. London: CBI/NUS.

Chan, C and Sher, W (2014) Exploring AEC education through collaborative learning, Engineering, *Construction and Architectural Management*, 21(**5**), 532-550.

Christensen, M and Probst, B (2015) Barbara's story: A thematic analysis of a relative's reflection of being in the intensive care unit, *Nursing in Critical Care*, 20(**2**), 63-70.

CIOB (2019) *Shortage Occupations in Construction: A Cross-Industry Research Report*. Bracknell: CIOB.

Cotton, J (1995) *The Theory of Learning: An Introduction*. London: Kogan Page Ltd.

Davison, G (2011) *Investigating the Relationships Between Authentic Assessment and the Development of Learner Autonomy*. PhD Thesis, University of Northumbria at Newcastle.

Deneen, C and Boud, D (2014) Patterns of resistance in managing assessment change, *Assessment and Evaluation in Higher Education*, 39(**5**), 577-591.

Eastcott, D and Farmer, B (1995) Learning to learn. *In*: M Waterhouse and G Crook (Eds.) *Management and Business Skills in the Built Environment*. London: Spon Publications Ltd.

European Commission/EACEA/Eurydice (2014) *Modernisation of Higher Education in Europe: Access, Retention and Employability 2014*. Eurydice Report, Luxembourg: Publications Office of the European Union.

Gray, D E (2014) *Doing Research in the Real World*. London: Sage Publications Ltd.

Green, B (2015) *Understanding the Value of Professionals and Professional Bodies.* Bracknell: The Chartered Institute of Building.

Honey, P and Mumford, A (1992) *The Manual of Learning Styles*. Maidenhead, UK: Peter Honey.

James, L T and Casidy, R (2018) Authentic assessment in business education: Its effects on student satisfaction and promoting behaviour, *Studies in Higher Education*, 43(**3**), 401-415.

Joseph, S and Juwah, C (2012) Using constructive alignment theory to develop nursing skills curricula, *Nurse Education in Practice*, 12(**1**), 52-59.

Knight, P and Yorke, M (2003) Employability and good learning in higher education. *Teaching in Higher Education*, 8(**1**), 3-16.

Leitch, S (2006) *Prosperity for All in the Global Economy - World Class Skills*. London: HM Treasury.

Newman, I and Benz, C R (1998) *Qualitative - Quantitative Research Methodology: Exploring the Interactive Continuum*. Illinois: Southern Illinois University.

Olawale, Y (2015) The employability skills provision within a construction project management degree programme. *In*: Raidén, A B and Aboagye-Nimo, E (Eds.) *Proceedings of the 31st Annual ARCOM Conference*, 7-9 September 2015, University of Lincoln. Association of Researchers in Construction Management, 959-968.

Ornellas, A, Falkner, K and Edman Stalbrandt, E (2019) Enhancing graduates' employability skills through authentic learning approaches, *Higher Education, Skills and Work-Based Learning*, 9(**1**) 107-120.

Quarterman, M (2017) *Acquisition of Higher-Order Professional Competencies: A New Synergistic Learning Model*. PhD Thesis, Department of Engineering and the Built Environment, Anglia Ruskin University.

Rawlins, J and Marasini, M (2011) Are the construction graduates on CIOB accredited degree courses meeting the skills required by the industry? *In*: Egbu, C and Lou, E C W (Eds.) *Proceedings of the 27th Annual ARCOM Conference*, 5-7 September 2011, Bristol. Association of Researchers in Construction Management, 167-174.

Rodeiro, C L V and Nádas, R (2010) *Effects of Modularisation*. Cambridge: Cambridge Assessment.

Rubenson, K (2010) The field of adult education: An overview. *In*: K Rubenson (Ed.) 2011, *Adult Learning and Education*. Oxford: Elsevier.

Smith, A, Burnett, K, Purcell, W, Bradshaw, T, Docherty, D and Worthington, S (2012) *One Step Beyond: Making the Most of Post-Graduate Education*. London: Department for Business, Innovation and Skills.

Swanson, D J (2011) The student-run public relations firm in an undergraduate program: reaching learning and professional development goals through 'real world' experience, *Public Relations Review*, 37(**5**) 499-505.

Teagle, A, George, M, Gainsborough, N, Haq, I and Okorie, M (2017) Preparing medical students for clinical practice: Easing the transition. *Perspectives on Medical Education*, 6(**4**), 277-280.

Whitelock, D and Cross, S (2011) Academics understanding of authentic assessment. *In*: *International Computer Assisted Assessment (CAA) Conference, Research into E-Assessment*, 5-6 July 2011, Southampton, 1-10.

Witt, E, Lill, I, Malalgoda, C, Siriwardena, M, Thayaparan, M, Amaratunga, D and Kaklauskas, A (2013) Towards a framework for closer university-industry collaboration in educating built environment professionals, *International Journal of Strategic Property Management*, 17(**2**), 114-132.

Wu, X V, Heng, M A and Wang, W (2015) Nursing students' experiences with the use of authentic assessment rubric and case approach in the clinical laboratories, *Nurse Education Today*, 35(**4**), 549-555.

Yorke, M (2006) *Employability in Higher Education: What It is - What It is Not*. York: Advance HE.

BOUNDARY OBJECTS: SUPPORTING BETTER COLLABORATIVE PRACTICE AND RESEARCH

Henrik Buhl[1], Michael Andersen[2] and Anne Klitgaard[3]

[1] *Copenhagen School of Design and Technology, Prinsesse Charlottes Gade 38, DK-2200, København N, Denmark*

[2&3] *University College of Northern Denmark, UCN Technology, Sofiendalsvej 60, DK-9200 Aalborg SV, Denmark*

The purpose of this paper is to look for boundary objects that can develop and facilitate a "knowledge base", which can facilitate collaboration between faculty and industry. The paper investigates the meaning of boundary objects. It is a conceptual paper with an empirical example. The empirical example is from a Danish (global) supplier engaged in a development project with technical aid (tools) in mounting and assembling gypsum walls. The example demonstrates how the use of boundary objects help the supplier to gain an understanding of different professional practices and aid the transformation to utilise smarter tools. The concept of boundary objects enables an understanding of the epistemological difference inherent in the process of collaboration and research between the university and the wider construction industry. Boundary objects can be used to improve present technical understanding and further its implementation, which is a valuable function for applied research institutions depending on collaboration from a broad range of stakeholder groups. A three-step phase model is suggested for the use of boundary objects to develop and improve present and new practices and technologies.

Keywords: Applied research, automation, boundary objects, collaboration, knowledge

INTRODUCTION

The research in this paper is about applied research and collaboration with industry facilitated by a university of applied research. Vocational university colleges offer educational programmes at bachelor level and lower as well as continuing development programmes for professionals. In the Danish educational sector, the emphasis is on the connection between research, education and industry, complying with methods and standards from the "Frascati Manual 2015" (OECD 2015). The educational activities are built upon a knowledge base about practice, which is created in collaboration with practice.

The Danish Accreditation Council secures high quality and relevance in this type of higher education programme. The council will only accredit an educational programme if it lives up to certain quality criteria. One of these relates to the knowledge base of the education. The educational institution must have *"a practice which ensures that education and teaching is constantly based upon a knowledge base…[the] knowledge base includes the institution's strategic and practical work*

[1] hebu@kea.dk

Buhl, H, Andersen, M and Klitgaard, A (2019) Boundary Objects: Supporting Better Collaborative Practice and Research *In:* Gorse, C and Neilson, C J (Eds) *Proceedings of the 35th Annual ARCOM Conference,* 2-4 September 2019, Leeds, UK, Association of Researchers in Construction Management, 174-182.

which must ensure that relevant end updated knowledge forms the basis for the programs and that this knowledge is part of the ongoing teaching" (The Danish Accreditation Council 2019). Accordingly, the knowledge base is characterised as being close to professional practice, so the teaching becomes based on the latest knowledge created in close interaction with the industry, research environments and the labour market that the programmes target. This means that the continued development of the knowledge base must consider different practices.

The paper investigates how this knowledge base can be developed through collaborative arrangements that are empathetic to each community's characteristics, and how it becomes possible to produce high-quality scholarship for the researcher as well as actionable knowledge for the industry (Sexton and Lu 2009). The initial idea was that the knowledge base consists of boundary objects between the Applied Research University and practice/industry. However, during scrutiny of the knowledge base it became clear that although the knowledge base had many different representations, none of these where used by practice to translate their knowledge to the institutions. After some consideration the paper will instead deal with how different boundary object and the understanding of boundary objects can support the work with developing the knowledge base as a space for knowledge sharing and/or innovation in collaborative projects.

The work presented puts emphasis on new technology and practitioners from an industry working with digitalisation and automation in construction. Technologies are complex artefacts which on the one hand are constituted of multiple, interrelated physical and virtual materialities and on the other hand are inherently tied to social practices. In that context, artefacts do not have stable boundaries that one can point to and rely on. They develop through their continued use, organisation and placement. This view treats design and technology less as a stable outcome, and more as a continually emergent phenomenon.

By using the concept of boundary objects, this paper sheds light on epistemological differences among disparate parties. Boundary objects can be seen as a 'tool' to create a shared syntax or language, which enables participants from different communities to represent their knowledge and communicate across boundaries about their concerns or questions about a practice or idea and transform their own knowledge into innovative solutions (Carlile 2002). A boundary object can establish a working relationship around a particular issue, idea or innovative practice about which communities of practice or knowledge are normally separated.

The paper pursues two research questions: - How can boundary objects mediate knowledge sharing between applied research universities and industry practices? - What other objects or artefacts can mediate knowledge sharing between participants in the transformation of construction processes?

The paper is conceptual with an empirical example. In the following section, the paper examines the meaning of Boundary Objects, contributions and perspectives. The next section presents and analyses the paper's empirical example: A research and development project between an applied research institution and a global supply company. The purpose of the applied research project is automation and how to generate new materials, procedures and processes, with new technology (digital tools and robots), looking into a case on drywall installation. In the conclusion a three-step phase model is suggested for the use of boundary objects to develop and improve present and new practices and technologies.

Theoretical Perspectives

Knowledge boundaries have been closely studied over the past decades. A boundary can be seen as a sociocultural difference leading to discontinuity in action or interaction. The more specialized a practice becomes, the more explicit the boundaries towards other practices become. Boundary objects are used by individuals to overcome these knowledge barriers. Boundary objects are entities that enhance the capacity of an idea, theory or practice, in order to translate across culturally defined boundaries - for example between communities of knowledge or practice. This concept thus has the potential to explain, predict, mediate, and facilitate collaboration about technology implementation (Fox 2011).

Four relatively stable objects (repositories, ideal types, coincident boundaries and standardized forms) have been introduced by Star and Griesemer (1989), who emphasizes that boundary objects are both plastic enough to adapt to local needs and the constraints of parties employing them, yet robust enough to maintain a common identity across sites (Star and Griesemer 1989, 393). The dynamics of boundary objects is threefold, explains Star (2010, 604): *"[1.] The object (remember, to read this as a set of work arrangements that are at once material and processual) resides between social worlds (or communities of practice) where it is ill structured, [2.] When necessary, the object is worked on by local groups who maintain its vaguer identity as a common object, while making it more specific, more tailored to local use within a social world, and therefore useful for work that is NOT interdisciplinary and [3.] Groups that are cooperating without consensus tack back-and-forth between both forms of the object."* Boundary objects are thus useful for the communities both due to their function which enable communication between practices but also in situations, where no communication across the boundary is necessary.

Objects are not born as boundary objects. They become boundary objects within situated practices, when*: 1) they establish a shared language with which individuals can represent their knowledge; 2) they provide concrete means for individuals to specify and learn about their differences; and 3) they facilitate a process whereby individuals can transform the knowledge being used* (Gherardi 2012 91). Boundary objects will therefore only become boundary objects when the communicating practices transform them into boundary objects.

As not all objects become boundary objects, objects have been under close scrutiny. Some objects can be artefacts. Whyte and Harty (2010) study collaboration in *"shifting ecologies of hybrid practice"* in the design and construction of a large European building project. They characterize the role of the artefacts as follows: *"Objects had a dual epistemic and boundary-spanning role, allowing participants in the project to maintain connections and legibility of objects, across different locations and ties, while allowing flexibility and partiality to enable the development of new ideas and innovation",* (Whyte and Harty 2012, 201). The artefacts were continuously iterated. Consequently, they were plastic enough to hold the information stable at the same time as they allowed it to be changed. The artefacts took a role as partisans when conflicts around their coordination emerged. For instance, conflicts and debates between expert groups arose requiring negotiation about the central or peripheral status of information given by the expert groups in the project. The production (or transformation of objects into boundary objects) of boundary objects (objects are developed, evolved and discarded) is an ongoing socio-material practice. (Whyte and Harty 2012, 205).

BIM challenges the basic conceptions of design collaborations argues Paavola and Miettinen (2018), who finds that Ewenstein and Whyte (2009, p.10) misses a concrete thing-like artefacts or objects, which are at the same time modifiable and editable, or concrete and dynamic. They call them (co-developed) intermediary objects, which refers to all kinds of artefacts in a design process (Table 1). The use of the artefacts can have a mediating function and help the process of double stimulation (Haapasaari and Kerosuo 2014). The process of double stimulation is a complex process of development, which opens for personal agency to be expressed through the use of external resources (Sannino 2015).

To wrap up the above theoretical perspectives on boundary objects, objects and artefacts, Paavola and Miettinen's (2018) table is presented below. They have added an "Intermediary object" to Ewenstein and Whyte's (2009, 10) understanding of evolving objects and made a distinction between 'boundary objects', 'epistemic objects', and 'technical objects' (Table 1).

Technical objects do not always function as boundary objects. They are defined by Ewenstein and Whyte (2009) as able to "provide a frame for the objects of inquiry and involve the taken-for-granted equipment and tools." If practices view an object from this perspective, they will be concerned with what the tool can do (its specifications) rather than using the objects to translate meaning across boundaries.

Table 1: A comparison of characteristics of concepts 'boundary object', 'epistemic object' 'technical object' and '(co-developed) intermediary object'; the first three adapted from Ewenstein and Whyte, 2009, 10. (Paavola and Miettinen, 2018)

	Boundary object	Epistemic object	Technical object	(Co-developed) Intermediary object
Nature of the object	Concrete (e.g. a timeline of a project)	Abstract (e.g. a working hypothesis of a research project)	Concrete (e.g. an equipment used in a project)	Concrete, and reworkable (e.g. a versioned BIM-model)
Role over time	(Relatively) stable	In flux	Static	Modifiable and versioned
Function in activity	Allow interoperability and communication	Generates new open questions and issues for going further in the research	A means or an instrument for accomplishing something	Gives tangible intermediate means for working towards an end result

The following example presents a project about automation in the construction industry. Table 1 has become the paper's conceptual understanding and tool for questioning (knowledge), facilitation (mediation) and analysis. This helps to find and analyse boundary objects and share a knowledge base about automation within build environments and construction processes.

Empirical Example: Project on Automation

This example is from a research project on 'Automation and Robots in Construction'. The project is initiated and funded by a global supplier of construction materials and University College Northern Denmark (UCN). The example is based on several

meetings and interviews between two researchers from UCN and three employees from the supply company's R&D department in Scandinavia. Through interviews with these employees and access to their empirical materials and data (reports and presentations, as well as videos and transcribed interviews made by an Industrial Designer), researchers from UCN were able to study the value chain as well as mapping the global supplier's internal development process in retrospect. The supplier's investigations of the mounting and assembly process performed by practices on site is based on an inherent assumption that the mounting and assembly of gypsum walls includes challenges related to automation (technical aids).

The industrial designer's work consisted of two methods: Participant observations in the field and interviews with employees of the gypsum installers, with the developer of the technical aid (product development consultancy company), and with internal employees of the supplier.

The drywall installation is part of a construction contract of a huge new extension building to a large hospital in Denmark. The contract comprises several thousand square meters of plaster walls and ceilings. The supplier delivers a wide variety of plaster systems, i.e. different products composed in different ways depending on the use, such as x-ray rooms, bedrooms, depots, etc. The products come from different production factories across Europe and are not necessarily packaged in the same way.

The installation of gypsum walls involves many challenges and disturbances for the craftsmen. Including getting an understanding of where the many systems/products must be installed, finding space enough for materials, as well as room to manoeuvre around with the technical aids (a tool for lifting plasterboards and a "vehicle" to transport the plasterboards). Despite the use of technical aids, the gypsum board installation process involves manual handling of boards. An example is working in limited space with technical aids or when working in height, where boards or pieces of boards have to be carried and lifted into the right position on a scaffold by hand.

FINDINGS AND DISCUSSION

In this case, the participants' boundaries are defined as sociocultural differences that give rise to discontinuities in interaction and action. The case looks at three different groups of participants that encounter discontinuities in their action and interactions around a gypsum board installation process on the construction site. The experiences of these participants illustrate the ambiguity of boundaries (Akkerman and Bakker 2011, 133).

Materials and Process - Different Meanings as Boundary Objects

In the first and second example, the paper looks at the craftsmen's challenges and disturbances with the drywall installation process and the materials. They experience too many systems/products and a vehicle for moving things around which is difficult to use. This analysis is based on interviews with the Industrial Designer and transcribed interviews between her and the contract manager and a drywall installation craftsman from the company contracted to do the work.

In the first example, the participants created a mental model of different types of gypsum boards during the project. The model was not concrete, yet still stable enough for the individual craftsmen to have a kind of understanding of such a model. This became a boundary object operating at a pragmatic knowledge barrier as it "depicts or demonstrate current or possible form, fit, and function of the differences and dependencies identified at the boundary" (Carlile 2002). All three practices discussed

the boundary object from their practices. The contract manager is concerned with the logistics of the different types of boards and wishes to minimise the variety of materials on site; the drywall installer is worried about the heavy lifts of the boards while the global supplier's perspective is the sale of plasterboards. The global supplier transforms her knowledge. She presumed that a high complexity of boards would exclude competing suppliers, but her knowledge is transformed into also considering the customer's (site manager) and the user's (drywall installer) practice.

In the second example, the practices transform the vehicle (considered a tool for moving boards) as a boundary object, as they are discussing it as a model rather than a 'taken for granted' tool. The contract manager is concerned with the logistics of storing and moving plasterboards on site while the drywall installers focus on the availability of the tool. The industrial designer (supplier) transforms her knowledge and sees the tool as a means to increase sales. Had the practices viewed the tool as a technical tool, the discussion would have focused on what the individual tool could do (or not do). In the same episode, the use of a technical tool (the drawings) is used as a mediating artefact to solve the problem of explaining how the drywall installers work. The tool (a camera) used to take the picture is being used as a technical piece of equipment. This action does not interact with the practices' knowledge base

Both examples show, despite a common interaction on the construction site, that the participants have different approaches in their view of challenges associated with the mounting gypsum walls. Carlile (2002, 444) describes this situation as "a semantic knowledge barrier" which recognises that even if a common syntax or language is present, communication and collaboration becomes difficult due to interpretations. In this situation, the technical objects, such as materials, work processes and the vehicle tool, cannot be designed as boundary objects, since their social meanings have not been transformed to a common importance among the participants. In this case, the objects have negative meanings for a community of practice, with consequences for the transformation of knowledge within that community (Fox 2011, 81) and can be considered as inhibitory in promoting the further development of processes and materials.

Development of a Technical Aid - the Technology as a Boundary Object

The third example analyses the technical aid for lifting plasterboards. The paper employs knowledge from interviews from the industrial designer, and her observations of craftsmen's practices, processes, collaboration and artefacts, which she has documented on video.

The analysis focuses on the social meanings related to the object (the technical aid for lifting plasterboards) performing a function as a boundary object in relation to knowledge transfer between different communities (Fox 2011, 80), in this case between the developer of the technical aid, the gypsum installer and the supplier. Focus was to discover whether a technical object (the technical aid for lifting plasterboards) can be transformed into a boundary object which can transfer knowledge between different communities, in this case between the developer of the technical aid, the drywall installer and the supplier.

The paper found that the prototype technical aid version 1 was not used on site but had its place in the corner, where it is obstructed movement on site. At the request of the supplier, a new development process began as an experiment. The process was organised so it would become possible to understand and interact with the existing technical aid version 1. Subsequently, the development process became an interactive

development process where the developer was alternating between developing his technical aid at the workshop and then testing it in practice in interaction with the gypsum installer and the supplier, and then returning to his workshop to improve and optimize the aid.

By moving a part of the development process to the construction site, the boundary object was established. This is 'a pragmatic approach' which refers to transforming a knowledge process from altering current knowledge to creating new knowledge. The participants are validating the knowledge within each function and collectively across functions at the prototype (Carlile 2002, 445) - the technical aid version 1. For instance, in a situation on the construction site, the developer, the drywall installers and the supplier are discussing the working process while they are testing the technical aid. During the conversation between them, the drywall installers point at the transverse arm which holds the plasterboard and say; "Look, it's more stable than the previous one. It makes the plasterboard much easier to mount". This example shows that by providing situations where the participants can communicate their questions and ideas across boundaries, the participants allow their different knowledge communities to transform their knowledge in the light of the innovation or idea (Carlile 2002, 452). As the process moves through development, the technical aid becomes a boundary object as a result of negotiations as a part of the learning-by-doing process. It is the start of a change in the participants' common approach, reflecting the new knowledge and practices used to produce them.

Concluding Reflections

Research institutions need to consider new ways to mediate knowledge sharing between applied research universities and industry practices/practitioners. The use of boundary objects has been demonstrated as useful for overcoming knowledge barriers between practices. The purpose of this paper is to establish and enable knowledge sharing and growth between educational and applied research and industry practice and innovation, which are two very different practices with different perspectives.

A socio-technically informed vocabulary using terms like: 'social-technical systems', 'sociomaterial designer', 'user participation', 'user-driven design', 'robotics', 'technical aid', 'automation' and 'reflective practitioner' can aid this collaboration. We have found concepts that have the capacity to be transformed into boundary objects.

The case discussed in the paper focus on a technical tool as a boundary object. By the nature of the case, the facilitative boundary object became a user-driven design and a technical aid. These boundary objects were on the project level, but in the concrete case "Drywall installation - a product development process" we have focused on the "technical aid", a technical tool that makes it possible to share knowledge. A technical tool can, therefore, be used as a boundary object by discussing it as a model rather than a piece of equipment. This allows for a stable object, which can overcome the barrier between practices, so it becomes possible to represent, learn and transform knowledge bases via the object. This is a starting point for discussions between different practices in co-production projects.

The understanding of objects and the use of boundary objects is useful for overcoming knowledge barriers between practices. Different types of boundary objects exist, some of them can be of a technical nature. However, it is the participants' ability to consider the technical tool, not as a technical object but as a boundary object, which allows the practices to jointly transform their knowledge.

In the work on this paper, it has become clear that when applied research universities works on a common knowledge base with companies from practice, it can be thought of as three entangled phases where boundary objects can advantageously be used:

Phase 1: "Explore practice" - companies and institutions collaborating together to gain an understanding of practice. The characteristics of different issues can thus be determined. Data and material should be gathered through documents, interviews, observations, meetings, workshops etc.

Phase 2:" Research practice" (epistemic processes) - The companies and institutions can together and individually research with the possible theoretical and technological perspectives and will thus discover issues for further research. The academic theoretical perspective will challenge the company in these development projects and its understanding of technology. The researchers can develop epistemic objects based on data collection. The research knowledge will then be communicated to the industry at large.

Phase 3:" Develop practice" - The companies and institutions can appreciate the new applications of technology and organizational forms. Intermediary objects can be used to further improve co-created processes with the emphasis on interorganizational collaboration.

In further work, the researcher should aid the participants to create these boundary objects, so the transformation of knowledge can take place. This will also allow the researcher to gain knowledge of the involved practices, beliefs, values and significances. New ideas or innovations introduced by the researcher in co-productions will then be easier to implement. In this way, boundary objects become key in a joint-practice research project between different practices, also when it is between the research community and industry.

REFERENCES

Akkerman, S F and Bakker, A (2011) Boundary crossing and boundary objects, *Review of Educational Research*, 81(**2**), 132-169.

The Danish Accreditation Council (2019) Available from https://akkrediteringsraadet.dk/publikationer/notat-vurdering-af-professions-og-erhvervsrettede-uddannelsers-videngrundlag/ [29/06/2016].

Bechky, B A (2003) Sharing meaning across occupational communities: The transformation of understanding on a production floor, *Organization Science*, 14(**3**), 312-330.

Boyd, D (2013) Using events to connect thinking and doing in knowledge management, *Construction Management and Economics*, 31(**11**), 1144-1159.

Brok, L S and Hasse, C (Eds.) (2015) *TEKU-Modellen - Teknologiforståelse I Professionerne* Copenhagen: U Press.

Cardinal, L B, Alessandri, T M and Turner, S F (2001) Knowledge codifiability, resources and science-based innovation, *Journal of Knowledge Management*, 5(**2**), 195-204.

Carlile, P R (2002) A Pragmatic view of knowledge and boundaries: Boundary objects in new product development, *Organization Science*, 13(**4**), 442-455.

Dowsett, R, Harty, C and Davies, R (2017) Epistemological Differences and New Technology in Construction *In:* Chan, P W and Neilson, C J (Eds) *Proceeding of the 33rd Annual ARCOM Conference*, 4-6 September 2017, Cambridge, UK, Association of Researchers in Construction Management, 714-723.

Ewenstein, B and Whyte, J (2009) Knowledge practices in design: The role of visual representations as `epistemic objects', *Organizational Studies*, 30(**1**), 7-30.

Gherardi, S (2012) *How to Conduct a Practice-Based Study: Problems and Methods*. Cheltenham, UK: Edward Elgar.

Gustavsson, T K (2015) Boundary action in construction projects: New collaborative project practices, *International Journal of Managing Projects in Business*, 5(**3**), 364-376.

Fox, N J (2011) Boundary objects, social meanings and the success of new technologies, *Sociology*, 45(**1**), 70-85.

Haapasaari, A and Kerosuo, H (2015) Transformative agency: The challenges of sustainability in a long chain of double stimulation, *Learning, Culture and Social Interaction*, 4, 37-47.

OECD (2015) *Frascati Manual 2015: Guidelines for Collecting and Reporting Data on Research and Experimental Development, the Measurement of Scientific, Technological and Innovation Activities*, Paris: OECD Publishing.

Paavola, S and Miettinen, R (2018) Dynamics of design collaboration BIM models as intermediary digital objects, *Computer Supported Cooperative Work*, 27(**3-6**), 1113-1135.

Sannino, A (2015) The principle of double stimulation: A path to volitional action, *Learning, Culture and Social Interaction*, 6, 1-15.

Sexton, M and Lu, S (2009) The challenges of creating actionable knowledge: An action research perspective, *Construction Management and Economics*, 27, 683-694.

Starr, S L and Griesemer J R (1989) Institutional ecology 'translations' and boundary objects: Amateurs and professionals in Berkeley's Museum of Vertebrate, *Social Studies of Science*, 19(**3**), 387-420.

Starr, S L (2010) This is not a boundary object: Reflections on the origin of a concept, *Science, Technology and Human Values*, 35(**5**), 601-617.

Whyte, J and Harty, C (2012) Socio-material practices of design coordination: Objects as plastic and partisan, *In*: P M Leonardi, B A Nardi and J Kallinikos (Eds.) *Materiality and Organizing: Social Interaction in a Technological World*. Oxford: Oxford University Press, 196-213.

MAKING SPACE FOR CONSTRUCTION PRODUCTIVITY STUDIES

SPACE ODDITY: SPATIAL DESIGN STRATEGIES AND WORK PLACE DESIGN

Peter Raisbeck[1]

Faculty of Architecture Building and Planning, University of Melbourne, Masson Road, Parkville, Victoria 3010, Australia

Spatial considerations are critical to the area of workplace design. However, what are the different spatial strategies at play in the negotiation and design of space in new workplaces? This question is explored via an examination of one company's workplace design project. As it moved to a new workplace this company chose to employ Activity Based Working (ABW) in the design. Through semi-structured interviews with the managers and designers, the design and planning practices for this project are outlined. The focus is on the early stage design strategies that set the spatial configuration of the workplace. This is in contrast to research orientations that measure workplace design outcomes in quantitative terms. For example, measuring health or productivity outcomes after the workplace is completed. In the design process a number of spatial organising principles are identified and named as: centering, mobilising, targeting and theming. It will be found that the spatial strategies employed in this workplace design are governed by concepts of corporate strategy, leadership and power. The study concludes by suggesting that workplace research must have both a spatial and an ethnographic dimension to be effective. Moreover, the production of space in this project exemplifies the transformation of work into a spatial system that facilitates industrialised knowledge work.

Keywords: work places, activity-based working, design, design strategies, space

INTRODUCTION

Workplace design is critical to the successful delivery of workplaces. The design of workplaces as it is currently practised by architects, interior designers, project managers, as well as organisational experts, is linked to a number of complex factors. As large organisations have moved to new digital platforms, they have sought to become more efficient whilst simultaneously meeting both staff and customer needs. The digital transformation of work in large organisations and has seen a shift to Activity Based Working (ABW). ABW is based on the idea that in workplaces, employees do not need to be positioned in the same place over time. Instead, employees are given optimal spaces that better suit the employees' immediate activity or task. ABW is seen as a response to a greater focus on technology, knowledge management and new organisational forms in workplaces.

However, as this transformation to ABW has taken place, numerous methods have emerged about the best ways to measure productivity and happiness in workspaces, such as the Leesman index (Leesman, 2018). As Engelen *et al.,* (2018) found ABW literature clusters around post-occupancy studies and health outcomes (Engelen *et al.,*

[1] raisbeck@unimelb.edu.au

Raisbeck, P (2019) Space Oddity: Spatial Design Strategies and Work Place Design *In:* Gorse, C and Neilson, C J (Eds) *Proceedings of the 35th Annual ARCOM Conference,* 2-4 September 2019, Leeds, UK, Association of Researchers in Construction Management, 184-193.

2018). They note in their survey of ABW research, the emphasis is often on the potential health benefits of ABW. Indeed, much of the work in the area is focused on notions of well-being and issues concerning the production of space are not factored into this.

In this study, an evaluative critique is developed regarding the production of space in one large workplace design. This project was a new 4,500 square metre workplace design for an infrastructure provider whose staff workforce had outgrown its existing premises. Specifically, the study examines the interactions between the workplace client, particularly its leader, and the workplace design architects. This focus elucidates the spatial design strategies determined early on in the design process. Three interlinked research questions were posed: Firstly, what are the design practices evident in the design and negotiation of new workspaces? Secondly, how are these design practices shaped by organisational factors? Thirdly how do these practices and factors configure the spaces in which people work? To answer these questions, it is important to focus on the early client-architect activities related to the strategic briefing and conceptual design, prior to the project's construction and delivery. An improved focus on these strategic design processes is critical in understanding how workplace design shapes the spaces within a firm.

Definitions of Space as a Concept

Henri Lefebvre's rejection of Cartesian notions of absolute and ideal space has been the foundation and starting point of various organisational studies into space. Lefebvre argued that simply producing the objects that occupy space is different from the production of space (Lefebvre, 1991). In his book, the *Production of Space* Lefebvre gives an example of the production of space with reference to the "the current transformation of the perimeter of the Mediterranean into a leisure-oriented space for industrialised Europe" (Lefebvre, 1991, 58). For Lefebvre space was a material and social practice, and he argued that the political economy and production of space should be critiqued (Fuchs, 2018, para 3.2). For Lefebvre, a particular space is produced as a “combined and reciprocal interplay of material and social interaction” (Bosch-Sijtsema and Tjell, 2017, 1313).

While Lefebvre's approach to space underpins much research across different areas of knowledge, space is still seen as being an imprecise and vague concept (Weinfurtner and Seidl, 2019). For example, Chan, Räisänen and Lauche (2019) succinctly note space is a "contingent and contested" concept and that the "definition of space is never always stable." As a concept, space has a specific narrative and history in architecture in comparison to organisation studies or Construction Management. Certainly, in architecture—the discipline most closely related to workplace design—many of the narratives accounting for the production of space are shaped by aesthetic norms. In architectural theory, space is seen as a concept linked to notions of the sublime and aesthetic experience (Nesbitt, 2010). For modernist architects, space was stripped of decoration and seen as an instrument of social progress. For postmodern architects, space was centred on concepts of cultural meaning engendered by the use of historical elements (Rowe and Koetter, 1978).

In Construction Management studies, space appears to oscillate between two different schools of research. Firstly, there are those in Construction Management who see space as a "social phenomena" related to "collaboration and knowledge sharing" (Bosch-Sijtsema and Tjell, 2017). Then there are those researchers who see space as

being related to ideas of increased production and efficiency (Eastman and Sacks, 2008).

Workplaces Spaces in Organisational Studies

Marrewijk and Yanow (2010) have highlighted what they identify as a spatial turn in organisation studies and the focus on different kinds of spatial settings. More recently, as a result of this emphasis on space Weinfurtner and Seidl (2019) found that the literature on space in organisation studies clustered around several primary concepts. These concepts were identified as being spatial distribution, the positioning of space, spatial isolation, spatial differentiation, and the intersection of different spaces. This focus on space exists alongside those organisational researchers who argue that work and workers, rather than space, need to be the central focus in organisation studies (Delbridge and Sallaz, 2015). Delbridge and Sallaz, (2015) proclaim that workplaces are "work-worlds" and that these can be seen "as physical worlds, as worlds of hierarchy, as spaces of innovation, and as fields of actors" (1449). Other researchers have also questioned the emphasis on space in organisational studies. For example, Costas (2013) decries the emphasis on space in organisation studies and argues for the need to consider "movement and mobilities" (1467). Consequently, she identifies a kinetic elite of workers constantly on the move.

In organisational studies, different types of workplaces and the elements within them have also been examined. Betts (2006) studied corporate boardrooms, arguing that both aesthetic knowledge and power are a central consideration in the spatial studies of workplaces. Interestingly, Hirst and Humphreys (2013) conceptualises space in work settings in terms of edgelands. In this approach, she examines the "peripheral sites" and functional services, in this case the paper storage units that service office buildings. She concludes that "modernisation" of existing workplaces often involves promoting a pure image of an organisation that expels or hides seemingly outdated or unsightly functions. The above studies also highlight the aesthetic elements within workplaces. For example, Dale and Burrell (2010) identify an evident spatial rhetorics in a study of a financial services building They write: "This 'aestheticisation' of the workplace, they write, 'is combined, almost ironically, with the disappearance of the workplace itself as a workplace... displaced by quasi-constructions of town- or village-scapes ... and break-out rooms ... using colours, lighting and furnishings which do not evoke a place of labour and employment" (Dale and Burrell, 2010. Cited in van Marrewijk and Yanow, 2010, 5) Van Marrewijk (2010) argues aesthetics has to be "understood in the context of power, as managers and architects try to influence the aesthetic experience of organisational employees" (Van Marrewijk, 2010).

Workplace Spaces in Design and Construction Studies

In Construction Management researchers have focused on the workplaces that are an integral part of the design and construction process. In these cases, the focus is on normative notions of productivity (Eastman and Sacks, 2008). There have also been ethnographic studies that have looked at particular construction workplaces, including construction sites, off-site construction sites and project offices as well as architects' offices (Pink *et al.,* 2013). Other Construction Management researchers have used ethnographic methods to examine power in workplaces, but spaces or spatial elements are not often highlighted in these studies. Sage and Dainty (2011) study power in an architect's office point out the importance of considering practices that are non-verbal (Sage and Dainty 2011). Other CM researchers have used space as a concept to open

up new perspectives on organisational forms. Bosch-Sijtsema and Tjell (2017) in a study of three construction design teams, argue that considering space as a "social phenomena" is necessary if temporary project organisations are to be understood. Space Syntax theory has also been extensively applied across research fields. Space Syntax theory emerged in the work of Hillier who set out what he claims to be "a new theory of space as an aspect of social life" (Hillier, 1984). Space Syntax, despite the connotation of its name, is overtly planimetric and does not account for three-dimensional space. This bias is evident in a survey of space syntax research in health care. In this survey, Saif and Luo (2012) argue that space syntax is a theory that "allows the quantification of layouts, and unit spaces within a layout, so that the environment itself can produce independent variables in quantitative research" (98).

In the field of architecture DEGW founded in 1971 was a pioneer in the area of modern workplace design. DEGW was a research-based design company that developed expertise in strategic briefing and workplace planning. Central to the DEGW approach was the idea that "office buildings, are essentially based on layers of differing longevity" and that buildings were not fixed or static objects. DEGW theory and practice encompassed "the way organisations use space and the nature of the office and workspace they might need" (Smith 2017). This involved rejecting the idea of fixed and specialised typologies as a way to understand workplaces. DEGW proposed that workplaces, as well as buildings, could be seen as "nested systems of different durability" and not "fixed spaces and fabric of solid and void" (Smith 2017). Central to the DEGW ethic was the idea of architecture acting as a "a spatial order containing and expressing the systemic order of the institution it houses." Hence the DEGW approach was to privilege a "systemic rather than spatial conception" of buildings. (Duffy 1997, [2]008). It is important to note that the architectural firm at the centre of this study included a number of the architects who had previously worked for DEGW before it was absorbed into AECOM.

Research Context Approach and Methods

Project Selection: In the overall research project four workplace design projects were initially documented through interviews and data gathering. These were the infrastructure provider, a public insurance company, a co-workspace provider and a digital services platform. All of these companies were undergoing different levels of organisational change and digital transformation. After collecting data through interviews in each of these projects it was decided to focus on the infrastructure provider. This was for several reasons. Firstly, the infrastructure provider had a legacy of working in an industry (road construction) with a seemingly low technology base. However, the company was seeking to migrate to new customer-centric systems as its toll road infrastructure projects were being completed. Secondly, the company had appointed a new leader who was resetting the company's strategy. Thirdly, the company needed to move to the new office premises as it had outgrown its existing staff premises entirely. Of the four firms, it was the firm that appeared to have undergone the most organisational change.

Empirical Context: The interactions between the lead architect, from the project sponsor, and the client-side project leader were, targeted as the empirical context. This was in order to ascertain the design practices being employed early in the project. This is because at an early stage of design—before the formal documentation and

delivery of a workplace—organisational strategies, goals and directions are more easily apprehended. At the early stage of a workplace projects design practices often focus on spatial issues: briefing, strategic configuration, spatial sense-making, master planning and zoning and placement and positioning of functional spaces. At this stage, there will often be design strategies related to setting the aesthetic tone of the workplace.

Methodology: The project sponsors, the architects, had a preconceived idea regarding concepts of design value. The infrastructure provider desired to develop a positive corporate narrative around the design outcomes of the project. In order to contest these preconceptions, grounded theory enabled an approach that did not prefigure a hypothesis or particular models. Given the focus on spatial design strategies, it was thought that ‘‘the potential strength of grounded theory lies in its analytic power to theorise how meanings, actions, and social structures are constructed" (Chama, 2006: 151). In part, Charmaz (2006) was followed and thus far grounded theory methodology adopted here has two components. Firstly, to gather rich data, through a range of different methods were employed at this stage including, interviews, and the gathering of material information about the project. Secondly, to code the data with theoretical meaning, in this case, this was done as discussed below in order to highlight the spatial attributes evident in the data.

Research Methods: Project semi-structured interviews were conducted with project managers and architects with line management and design responsibilities. This dyad was not an effort to set up an adversarial outlook between clients and workplace design architects. Instead it was an effort to understand the early stages of the workplace design.

THE WORKPLACE DESIGN PROCESS

Completed in 2014 for an infrastructure company with revenues of $3.2 Billion the project was 4500 square metres in area which occupied two floors of a new office building. The office building was part of one of the biggest commercial office developments in Australia covering an entire block and being 200,000 square metres in size. For the offices of the infrastructure company, twenty per cent of the new area was to be allocated to ABW. Despite being a hybrid office, the project was nonetheless described as an "agile" working environment, and this also involved a number of interventions in the fabric of the new office building. The infrastructure company's move to the new office premises was managed through a change management process, and an internal change manager was a part of the overall team from the beginning of the project. The need for change management was not simply about moving to a larger office. It was also because at the time the organisation had shifted from being a developer of new infrastructure to be a developer and an operator of toll roads. However, some of these service functions were increasingly being outsourced. In the words of the client-side interview participant, the organisation was "driven by circumstance, and we did not think we were going to be successful with bids" which are then won resulting in "unprecedented growth" growth for the company.

Pre-Design Activities

The architects worked directly with the company's leader in order to prepare a strategic design brief. Central to the architect's approach was the idea of understanding the organisation's core business from first principles. They stated there

were not going to impose an ABW "off-the-shelf" plan. After the project the client-side participant perceived the architect as:

"very much was them understanding our business and understanding where [the leader] wanted to take the organisation and with that coming up with those high-level principles about what we were about how we wanted to work. And then from there, that was articulated, and then they did the design effectively to try and meet the high-level brief of what those objectives were."

The architects initially studied how the firm was utilising space in its existing accommodation. This study included conducting occupancy studies measuring and monitoring the company's existing ways of working.

To then begin the process of working through the brief the architects researched several different topics. They classified these topics into three categories. The first category was the "Company" itself which the architects saw as having a high profile, but, compared to other listed companies, was relatively small in terms of staff numbers with only 450 staff. The second category related to the "Existing workplace" and the existing workplace was described as "graphic," "bold," "internalised" and a "literal representation" of the company. The third category was called "Agile working" and the words used to describe this were "connected," "collaborative," "innovative" and "diverse." This research appeared to reflect back to the company, what the company may already have obviously known. In any case, as a result of this research the strategic brief that was formulated had three objectives. Firstly, need to reflect the brand of the organisation. Secondly, make a clear shift away from the aesthetics of the existing office. Thirdly, develop a new way of working and shifting towards a "partially agile working environment."

From the beginning of the above process the new leader drove the process with strategic leadership that posited that the workplace design was integral to the company's strategic management. However, this leadership also extended to direct involvement in the design. As was noted in the interviews the leader was the key decision maker, and a key goal in the words of the architect participant was to "build trust both ways." For the leader, one of the key strategic purposes of the project was to develop a new workplace that would help to attract and retain staff. Moreover, the leader wanted to engender a high degree of collaboration in the organisation's project bid teams. In the words of the lead architect.

"We tried to understand exactly how they work and the kind of work environment. They would prefer to work in there. And we designed it accordingly. So, there were high tables, collaboration tables, that they would stand around. Our client [the leader] was 6 foot 6, so he wanted to stand, and his table had to be really tall."

Spatial Configuration

Through the direct relationship between the architect and the leader, the design process proceeded over a very short period. At this stage there was minimal stakeholder consultation other than to make reference and clarify issues regarding the functional brief. Working closely with the leader the architects developed the spatial configuration of the new workplace. This was done by developing design studies that explored the different options for how front-of-house, reception, the staff hub, workspaces, and services spaces would be distributed over two floors. Often for workplace designers, the limited nature of large office floor plates makes it difficult to design a workplace with spaces of different height. The architects were able to do this

through three dimensional and spatial diagrams which they described as investigating "a range of site studies looking at: zoning, blocking, stacking, circulation, views and daylight." In this fashion, working back and forth between the design team (who generated the options) and the leader, different options were explored for the layout of the two floors. All the options were positioned around the pre-existing central atrium space. In addition, a wide circular stair was introduced to allow a connection between the two floors.

In the final iteration of the design, the staff hub space was grouped around the atrium. More importantly, the architects working with the leader negotiated with the building's owner (from whom the company was negotiating a long-term lease) in order to create a double height overlooking the surrounding urban context. This urban context was notable because it provided a clear view of the infrastructure the company had built and was then operating. The double height space provided staff with a place to meet, work or have a break. The internal fit-out of the building was based around the notion of curves (with extensive interior planting) which in the words of the designers "created a sense of continuous movement that mimics transport circulation."

CONCLUSIONS AND DISCUSSION

ABW cannot be configured through a spatial distribution of derived organisations functional zoning (e.g. office and boardroom) business units (e.g. sales and finance) or managerial hierarchies (e.g. executives and team leader). For this reason, ABW requires a new range of design practices in order to configure and structure workplace design space. In the design of this workplace, a number of spatial design practices were evident, and the results of these are also evident in the final physical office. These spatial design processes are described below and categorised as centering, mobilising, targeting and theming.

Centering

Design processes of centering were evident at several scales in the design process. Firstly, the atrium of the building was seen as a centre around which both floors would revolve. Secondly, the circular stair was seen as a central point and focus of the workplace design, and this was located near one corner of the front of house area, and the service functions. However, the process of centering also involved grouping different types of workplaces, around the building's atrium and also through the creation of different centres or focal points throughout the space. This centering was further emphasised through the use of circular geometries—it being axiomatic that geometry circles have a centre. Throughout the workplace, there is extensive use of circular meeting pods, circular furniture and low height partitions, as well as other circular lighting features. Interestingly, and perhaps treated as what Hirst and Humphreys (2013) denote as "edgelands." other services, including the workers' lockers, were decentred and located behind and adjacent to the building's service core.

Mobilising

In the publicity material, the architects posited that the design was intended to "reflects the rhythms of urban transport." In the words of the architect the purpose of the circular geometries in many of the elements of the workplace was to employ "curves and spirals to connect spaces, creating a sense of continuous movement that mimics transport circulation" Mobility was thus a key theme in the project, and this was achieved through a number of specific devices. These included an "undulating line of the green carpet" Other circulation paths were articulated though floor

coverings to link open work stations to collaboration spaces and the spiral balustrade at the centre of the connecting stair. Through these devices, the architects were able to emphasise the infrastructure companies' credentials and branding as a provider of toll roads. This was an approach that saw the workers of office as kinetic entities constantly mobilising themselves within the space as they move from project team to project team and from activity to activity.

Targeting

This sense of continuous movement that was engendered throughout the space meant that a person's line of sight walking through the office would shift from one centred circular element to the next. For example, a person entering the building from the buildings' street frontage would have a direct line of sight to the circular stair. However, as a person traverses this stair and walks through the next floor, they would then be presented with a series of different sight lines. Thus, a person walking around the space is led by their eye, their line of sight, from one centred target or element to the next. As one circulates through the workplace design, this culminates in sight lines that extend out of the workplace, directing the eye, to the surrounding urban context. Indeed, the two-story high veranda space is the ultimate focus or target of any person who chooses to work around the workplace. In this case, on the double height veranda, the sight lines lead to a new central focus or target, and that is a view to the monumental toll road constructed by the company.

Theming

The front of house area was coloured in grey, in order to evoke the dark grey concrete of the company's toll road infrastructure. However, in the workspaces the colour palette was very much green and white. In the words of the architects, the green landscaping across the two floors was a "nod to the urban landscaping that surrounds the company's roads." These efforts of theming points to a workplace design process that has sought to create a world within a world. Through these devices, spatial and aesthetic rhetoric creates a new experience for the worker who is working in and AW environment. This environment is not structured by expanses of open or closed cubicles, organisational functions or hierarchies. This environment is structured shaped through spaces with aesthetic themes that have created a cocooned and separate work-world. This workplace design is a work-world, a totally enclosed space of activities, dedicated to the corporation it serves. What is ironic is that the attributes of the old workplace described in the early site study of the architects as "graphic," "bold," "internalised" and a "literal representation" of the company. These attributes might also describe the themes of the new workplace. Theming was not only limited to the physical artefacts of the spaces. In the space between the reception area and the largest aggregation of meeting rooms was a wall of screens which displayed images in real time streamed from the company's road projects.

Implications and Further Research

As described, above the design practices evident in this workplace are related to spatial practices of centering, mobilising, targeting and theming. These spatial gestures appear to mimic processes of road construction or road travel itself. These gestures constitute a spatial system that resulted in the new workplace for the infrastructure company. In accord with the principles of DEGW this was not a design based on fixed typologies of architectural archetypes of solid-void. Whilst the themes of the office fit-out reflected the company's brand, the result was not an architectural monument to this brand. The office and the seemingly kinetic workers in it were part

of the company's broader system. In many respects, workplaces, and the deployment of Activity Based Working appears to suggest that workplaces, such as this one, are spatial-technical systems that do not need to represent themselves through traditional symbolic monuments. As it appears, the architects closely matched and followed the instructions and strategic wishes of the infrastructure company's leader.

Further research would examine, by using ethnographic methods, how the workers of this building perceive its spaces. Do these workers perceive the gestures identified here? The contribution of this short study is to show that issues of space in workplaces are multi-layered. This suggests quantitative studies of workplace productivity must extend to examine broader conceptions of spatiality in workplace design. These types of workplaces are spatial systems, work-worlds embedded in larger spatial systems. In this case, the workplace is a system connected to and embedded in the more extensive spatial system of the company's network of toll roads. What is described here is a production of space that reflects corporate power. As well the as way corporations employ Activity Based Working to respond to contingent realities and new forms of knowledge work. To return to Lefebvre, this is not "a leisure orientated space for Industrialised Europe." But this project indicates the transformation of work into a spatial system to facilitate new forms of industrialised knowledge work. Through the spatial practices of centering, targeting, mobilising and theming, this workplace is a representation of the corporation's strategy and brand. The spatial practices described here are akin to those used to produce the monumental toll roads of the company. In this workplace the kinetic workers gaze towards the company's monuments as they take a break from their green and white work-world.

REFERENCES

Betts, Jan (2006) Framing power: The case of the boardroom, *Consumption, Markets and Culture*, 9 (**2**), 157-67.

Bosch-Sijtsema, P M and Tjell, J (2017) The concept of project space: Studying construction project teams from a spatial perspective, *International Journal of Project Management*, 36(**7**), 1312-1321.

Chan, P W, Räisänen, C and Lauche, K (2019) Editorial: What's taking space? Re-framing space and place in everyday organizational life, *Scandinavian Journal of Management*, 35(**2**).

Charmaz, K (2006) *Constructing Grounded Theory: A Practical Guide Through Qualitative Analysis*. Thousand Oaks, CA.: Sage Publications.

Dale, K and Burrell, G (2008) *The Spaces of Organisation and the Organisation of Space: Power, Identity and Materiality At Work*. Basingstoke, UK: Palgrave Macmillan.

Eastman, C M and Sacks, R (2008) Relative productivity in the AEC industries in the United States for on-site and off-site activities, *Journal of Construction Engineering and Management*, 134(**7**), 517-526.

Engelen, L, Chau, J, Young, S, Mackey, M, Jeyapalan, D and Bauman, A (2019) Is activity-based working impacting health, work performance and perceptions? A systematic review, *Building Research and Information*, 47(**4**), 468-479.

Rowe, C and Koetter, F (1978) *Collage City*. Cambridge, MA: MIT Press.

Duffy, F (1997) *The New Office*. London: Conran Octopus.

Duffy, F (2008) Forum Linking theory back to practice, *Building Research and Information*, 36(**6**), 655-658.

Fuchs, C (2018) Henri Lefebvre's theory of the production of space and the critical theory of communication, *Communication Theory*, 29(2), 129-150

Hillier, B and H, Hanson, J (1984) *The Social Logic of Space*. Cambridge: Cambridge University Press.

Hirst, A and Humphreys, M (2013) Putting power in its place: The centrality of edgelands, *Organization Studies*, 34(**10**), 1505-1527.

Costas, J (2013) A metaphor of stickiness, non-places and the kinetic elite, *Organization Studies*, 34(**10**), 1467-1485.

Delbridge, R and Sallaz, J (2015) Work: Four worlds and ways of seeing, *Organization Studies*, 36(**11**), 1449-1462.

Leesman (2018) *What is the Leesman Index and What is It Measuring*? Available at https://www.leesmanindex.com/.

Lefevbre, H (1991) *The Production of Space*. Oxford: Blackwell.

Nesbitt, K (2010) The sublime and modern architecture: unmasking (an aesthetic of) abstraction, *New Literary History*, 26(1), 95-110.

Pink, S, Tutt, D and Dainty, A (Eds.) (2012) *Ethnographic Research in the Construction Industry*. Abingdon: Routledge.

Rashid, M, Kampschroer, K, Wineman, J and Zimring, C (2006) Spatial layout and face-to-face interaction in offices - A study of the mechanisms of spatial effects on face-to-face interaction, *Environment and Planning B: Planning and Design*, 33(**6**), 825-844.

Sage, D J and Dainty, A (2012) Understanding power within project work: The neglected role of material and embodied registers, *Engineering Project Organization Journal*, 2(**4**), 202-215.

Smith, S (2017) *City of Time - 'Site, Structure, Skin, Services, Space Plan, Stuff' and Then What?* DEGW Symposia Available at http://www.reading.ac.uk/architecture/degw-archive.aspx [Accessed 12/07/2019]

Saif, H and Luo, Y (20120 Space syntax in healthcare facilities research: A review, *Health Environments Research and Design Journal*, 5(**4**), 98-117.

Schmidt, R and Dainty, A (2015) The influence of practice culture on designed artefacts, *Architectural Research Quarterly*, 19(**4**), 397-409.

Van Marrewijk, A and Yanow, D (2010) The spatial turn in organisational studies. *In*: A Van Marrewijk and D Yanow (Eds.) *Organisational Spaces: Rematerializing the Workaday World*. Cheltenham, UK: Edward Elgar Publishing.

Van Marrewijk, A (2010) The beauty and the beast: The embodied experience of two corporate buildings. *In*: A Van Marrewijk and D Yanow (Eds.) *Organisational Spaces: Rematerializing the Workaday World*. Cheltenham, UK: Edward Elgar Publishing, 96-114.

Weinfurtner, T and Seidl, D (2019) Towards a spatial perspective: An integrative review of research on organisational space, Scandinavian Journal of Management 35(**2**).

WHY (NOT) MEASURING PRODUCTIVITY IN HOUSE-BUILDING COMPANIES?

Alexander Jimenez[1], Susanne Engström and Lars Stehn

Department of Civil, Environmental and Natural Resources Engineering, Division of Industrialised and sustainable construction, Luleå University of Technology, University Campus Porsön, SE-971 87 Luleà, Sweden

The need for improved productivity in construction, and the continuous tendency of lagging behind manufacturing industries in this respect, is a longstanding theme in the general debate in Sweden. However, there is a lack of consensus in how to understand and measure productivity, as well as in how to assess and compare productivity properly over time, between tasks, projects, companies and industries. This paper presents initial findings from the first step of an ongoing R&D study. The purpose of the R&D study is to develop frameworks for comparisons between productivity in different projects and suggest how these can be used for operational development. In this first step and by lending from two concepts proposed for measuring productivity at different levels in construction, understandings of productivity are identified and problematized together with findings collected during a one-day project-initiation workshop. Results indicate that different stakeholders understand productivity differently and have separate purposes for measuring productivity. The findings also point out that measuring productivity does not seem to be common practice in house-building companies. Furthermore, to measure productivity in ways that allows for relevant comparing of performance between sub-processes and projects seems especially problematic. Findings suggest that further research on how one can tackle differences between house-building projects is needed to understand better how to enable for assessments and comparisons of progress both in and between house-building sub-processes and projects. In addition, further investigation is required to understand how and where to set boundaries for productivity measurement frameworks to enable for meaningful measures without hampering value-adding activities.

Keywords: productivity, house-building, industry levels, productivity performance

INTRODUCTION

The need for improved productivity in construction, and the continuous tendency of lagging behind manufacturing industries in this respect, is a longstanding theme in the general debate in Sweden. However, there is a lack of consensus in whether or not the measurements generally presented by economics to underpin such arguments properly reflect the situation on single industry and project levels and among construction companies in general.

To increase performance, researchers such as Bresnen and Marshall (2001) describe that construction management has adopted different specializations by, for instance, implementing lean production, benchmarking techniques and total quality

[1] alexander.jimenez@ltu.se

Jimenez, A, Engström, S and Stehn, L (2019) Why (Not) Measuring Productivity in House-Building Companies? *In:* Gorse, C and Neilson, C J (Eds) *Proceedings of the 35th Annual ARCOM Conference,* 2-4 September 2019, Leeds, UK, Association of Researchers in Construction Management, 194-203.

management. Many of these take influence from the manufacturing industry, which has highly standardised, controlled processes that enable for measurements (Bresnen and Marshall, 2001). Yet, measuring productivity is still not a well-established practice among companies in the Swedish house-building industries. Even though construction project inputs are repetitive, to about 80 % according to some researchers (e.g., Egan, 1998) it is frequently suggested that methods and metrics from manufacturing industry do not fit house-building (HB) well due to its project-based nature incorporating multiple goals and purposes from the many stakeholders involved (Vogl and Abdel-Wahab, 2015). There also seems to be a lack of consensus in the fragmented construction sector on how to understand and measure productivity and what methods and metrics to use. For example, there are different definitions of productivity depending on what contextual factors are acknowledged, on the level of analysis and system boundaries currently applied, and what the purpose is of addressing productivity in the first place. Thus, it is inferred that no single framework for measuring productivity can possibly fit all cases (Yang, *et al.,* 2010; Crawford and Vogl, 2006; Huang, *et al.,* 2009). Frameworks also seem to fail in reflecting aspects that might have an impact on productivity, for instance new technologies (Bröchner and Olofsson, 2012). Still, little empirically grounded knowledge exists on how companies do reason and subsequently act in these respects. At the same time, subsequent to trends such as industrialization and digitalization, there is a growing interest among HB companies regarding the use of measurements and metrics for operational and even business performance improvement purposes. This paper presents initial findings from the first step of an ongoing R&D study. The purpose of the R&D study is to identify different productivity measures from the progress of sub-processes in HB projects to suggest frameworks for comparisons between the productivity in different projects and how these can be used for operational development. The research follows a R&D study in which four of the largest Swedish HB companies collaborate with researchers from production management, and construction management and building technology. The aim of the first step of this research is to identify and problematize understandings of productivity by lending from two concepts proposed for measuring productivity at different levels in construction. More specifically, in this paper the understandings of key-representatives at project outset are addressed including their:

- Perceived purposes for measuring productivity,
- Views on how to measure productivity (and not), and
- Challenges associated with measuring productivity for intended purposes.

Different Views on Productivity

Productivity is a slippery term with many interpretations. Tangen (2005) traces the definition of productivity back to Littré (1883) as “the faculty to produce”. Parting from that definition, productivity and productivity measurements have been interpreted and evolved in many ways depending on where it has been contextualized and the purpose for measuring productivity. One is the generic term of productivity that refers to the ratio of units of outputs/units of input (Chew, 1988). However, that term is broad and open for interpretations, and in construction, such as Huang, *et al.,* (2009) explain, productivity is measured differently and for different purposes depending on what level one assesses productivity on (industry, project and task).

There is a need to clarify how different understandings of productivity and productivity measures affect productivity in the case of productivity as a performance

measure in HB. Firstly, we need to unravel the different definitions of the methods for measuring productivity in use. Secondly, we need to state the influence on how the different levels (industry, project and task) affect measuring productivity and its influence on different stakeholders.

Productivity Measurement Methods

The generic definition of productivity has been operationalized in two different ways in the case of productivity as a performance measure in construction: Construction or Average Labour Productivity (CLP, ALP) and Total Factor Productivity (TFP) (Vogl and Abdel-Wahab, 2015).

Construction labour productivity (CLP) is a concept with many definitions but is primarily rooted in the belief that firms or industries produce similar products with almost the same capital intensities (Crawford and Vogl, 2006). The concept originates from the relation between labour cost and the quantity of outputs produced (Borcherding, *et al.,* 1986). Both CLP and Average Labour Productivity (ALP) are single-factor productivity measures that assess output by labour input (Vogl and Abdel-Wahab, 2015). As for being single factor measures, they have two main disadvantages; they leave out the importance of a system in its whole and the result is easy to manipulate as one can reach high levels of ALP by substituting capital for labour, neglecting to present the real performance of the process (Crawford and Vogl, 2006). The industry uses CLP for measuring the gross output-based labour productivity while statistical offices tend to set it as value-added labour productivity (Huang, *et al.,* 2009). ALP is commonly used as an indicator of total productivity performance for government policy objectives, as it relates to the income for hours worked and output for a given labour input.

Total Factor Productivity (TFP) is a multi-factor measure that tries to take into account the impact of inputs (labour, material, energy, technological progress, quality, etc.) on output (Crawford and Vogl, 2006). This could, in theory, give evidence for a more in-depth analysis of productivity changes (Chau and Walker, 1988; Crawford and Vogl, 2006; Bröchner, 2010; Wang, *et al.,* 2013). However, TFP does not come without disadvantages. Firstly, it needs a large amount of data, some of which difficult to measure that need qualitative expert assessment. Secondly, the different contexts of each construction project give unfair results if comparing the TFP between different projects.

CLP/ALP and TFP can be used for comparing performance (benchmarking) between projects, organizations and industries (Bresnen and Marshall, 2001). A common measure of inputs is key performance indicators (KPIs). KPIs are quantitative indicators hard to generalise from one context to another as they are based on company accounts and do not provide holistic explanations of the link between practice and performance (Fernie, *et al.,* 2006). However, Bröchner (2010) suggests that KPI based measures can be carried out for comparisons if done on component or task level.

Different Levels with Different Productivity Purposes

If construction performance measurements are carried out, they are performed differently depending on if it is done on industry, project, stakeholder or task level (Yang, *et al.,* 2010; Huang, *et al.,* 2009). As there are different purposes with the measurements on each level and the understanding of performance vary, the boundary of the production system - the base for productivity measures -is different in each

case, which in turn results in different frameworks for measuring performance. Thus, measurements are carried out on what can be called a system with many subsystems and parts from systems or systemic thinking (Atwater, *et al.,* 2008). Since construction is fragmented with multiple stakeholders on each level (industry, project and task), the goals for productivity measures might therefore be different for each stakeholder depending on the level studied which complicates for defining and comparing measures even more.

Firstly, Huang, *et al.,* (2009) define productivity on the industry level as "the amount of output produced per unit of input", which should provide a measure of industrial efficiency. At this level, one seeks to measure productivity for making comparisons between industries at the national or global market (Yang, *et al.,* 2010; Huang, *et al.,* 2009). These measurements show that construction is low productive when comparing with others such as the manufacturing industry; it is lagging behind (The Economist, 2017). However, when making the comparisons one neglects the increasing project complexity and the heterogenic nature of construction, and even if there are some measurements that have applied TFP, the most common way of measuring is by CLP or ALP (Crawford and Vogl, 2006). For instance, in Sweden, the industry level is assessed by an index based on the difference between the produced volume of value and working hours required to produce the output. What this measure actually shows is the change in economic activity within construction.

Secondly, at project level one looks at the collection of all tasks performed to construct new buildings or to renovate existing ones (Huang, *et al.,* 2009). The measure is used for comparing the project to an overall average in the reference data set or to identify productivity changes over time. The level includes different processes, aspects and stakeholders (Yang, *et al.,* 2010); and different tasks have different inputs and outputs. Huang, *et al.,* (2009) state that "each component of the project productivity metric contains a task weight, a raw task productivity baseline value, a raw task productivity value for the project, and a measure of the task mix". The result is an index value from a function of the individual components/tasks together. However, task level productivity does not count for factors such as regulation, idle time and managerial coordination and planning, which affect project-level productivity. There is no standard practice for measuring project-level productivity nor a standard database with metrics that cover the overall project-level productivity, which complicates the analysis of productivity and its driving factors. Another challenge in the analysis of project productivity is that used measures rather reflect changes in the composition of projects instead of productivity changes per se (Huang, *et al.,* 2009).

Thirdly, the stakeholder level refers to the measurement of a single stakeholder/company from the industry. Even if a construction project normally includes many stakeholders, productivity measurements on the stakeholder are rare or none. Instead, one looks at the overall stakeholder performance, which can have many different purposes besides productivity (Yang, *et al.,* 2010). However, depending on the stakeholder, the business, the contract and the mission, the stakeholder will affect or be affected by other stakeholders' productivity to a smaller or greater extent.

Lastly, the task level considers single activities for specific elements, such as the construction of a wall. Task level type of productivity measurements are more common and often in the form of single factor measures that focus on labour

productivity (Huang, *et al.,* 2009). There are different metrics depending on how one defines and measures task level productivity and thus different outputs depending on what one considers relevant in the context and for what purpose one measures productivity. However, tasks are isolated events within a process. Hence, as Huang, *et al.,* (2009) explain, they do not capture the whole process, failing to reflect a complete picture of industry and project level productivity. In addition, some methods include value-added inputs such as prefabrication of materials, while others do not (Huang, *et al.,* 2009).

METHOD

The first activity in step one of the research process, was a one-day project-initiation workshop. The general intentions of the workshop were to provide the opportunity to share and discuss understandings on productivity and to guide the design of the R&D study. The workshop gathered four key-representatives of the HB companies, i.e. managers in charge of production development, and an economist (invited as expert) representing a Swedish research institute that work with productivity measurements on national level. From here on, the four representatives from the Swedish HB companies are referred to as "industry practitioners 1-4 (IP 1-4)", and the expert representative of the Swedish research institute as the "researcher".

The workshop included semi-structured discussions and unstructured dialogues on "what is productivity", the purposes of measuring productivity, how the representatives' organizations work with/measure productivity, and participant's experiences and views of challenges associated with measuring productivity. Two researchers observed and took notes of the workshop. The semi-structured discussions were recorded in full.

Workshop observations were analysed parting from the generic definition of productivity operationalized in two concepts (CLP and TFP) acknowledging also viewpoints from different levels (e.g. industry, project, stakeholder, and task level).

FINDINGS

Perceived Purposes for Measuring Productivity

From the economist side, the researcher at the workshop indicated that productivity is a measure of industrial efficiency. The measure is based on the price of the product or value-added productivity and is measured at industry level and carried out with single factor measurements such as CLP.

> Gross-value is the ultimate measure of productivity and should in theory relate to the costs in HB. - Researcher

The industrial practitioners instead viewed productivity as a measure of progress in work.

> Productivity is progress in work. - IP 1

That is, a purpose for measuring productivity is that it should reflect the progress of operational work when constructing buildings. However, when discussing about the stakeholder and industry level, productivity is perceived as a measure that should reflect performance.

> There are both internal and external efficiency and effectiveness. Productivity relates to the internal efficiency and effectiveness, that is productivity; the external is the price we can sell the product for. - IP 3

The external efficiency view is expressed as a measure to assess performance within and between organizations.

Views on How to Measure Productivity (and Not)

On the national or the industry level, economists measure productivity to report the results to the ministry of finance. The purpose is to evaluate and compare productivity between industries based on value added productivity to report if there is any need for improvement. Based on the price, one should be able to analyse the results and connect them to how HB companies perform seen as an industry.

> On the industry level, one measures productivity on the different partitions in HB added together as one single industry. The purpose is not to steer the organization, it is to compare how the numbers evolve with respect to other industries. - Researcher

All IPs participating in the workshop did not see the point in using gross-value measurements for assessing and working with productivity. Production related costs are reported to higher organizational levels for evaluating the economic progress of projects and the company, serving for accounting purposes. Instead, the industry representatives expressed a desire for having methods using many sources in the measures for assessing productivity to primarily improve progress in activities or sub-processes in projects.

> One can have done a great project that still turned out very expensive. One can manage and use resources excellently and still not get effective results. - IP 2

However, the workshop also resulted in a common view that productivity measurements also should be a tool with potential to steer towards increased productivity. The perceived purpose was to improve not only progress in work but also performance to be able to evaluate and compare between tasks, projects and with other companies.

> If we do not measure at every level, we cannot really improve. - IP 2

> Comparing productivity between projects would be good. Also, between regions within an organization or between organizations. As for now, we cannot get a measure on whether we are good or bad. We can see what costs and income we have, but not if we are productive. - IP 1

Challenges Associated with Measuring Productivity for Intended Purposes

On the industry level, the main challenge voiced at the workshop had to do with the use of gross-value productivity as a measure working on the other levels. The existing measures on the industry level have their base in market prices and not the actual costs of the company. In addition, when measuring productivity at industry level, different sections from the construction sector are added together to produce a final measure. In this way, HB productivity and e.g., infrastructure productivity are lumped together.

> One studies how productivity in construction evolves as a whole in relation to other industries, but is it really meaningful to compare HB to other completely different industries? - Researcher

> In order to make comparable measures, one has to divide construction into smaller partitions." - IP 3

The matter of cost, in itself, and as intervened in the gross-value productivity, was another challenge mentioned. Costs are accounted for differently between projects and between the participating companies, and do not necessarily need to reflect the progress in work.

> One can build something with low costs but meet the client's expectations on many other levels to increase the price, which does not really reflect the costs. The price reflects willingness-to-pay, not productivity - IP 1

> We do not book costs in the same way between projects - IP 3

Another challenge mentioned at the workshop was that the HB companies often estimate task level progression but not task level productivity per se. The first part of the challenge had to do with problems of comparing progression. The second part of the challenge had to do with not measuring productivity as such but using other proxies.

Firstly, it appeared that there was always a contextually "clouded" blame so that no one could really explain why the task level results and results on the project level were different in each case and why they were not comparable from case to case.

> Sub-processes are measured, but there are problems in comparing between projects, even harder between regions and companies. - IP 1

> Requirements change due to variations in regulations; it is difficult to find point-zero. - IP 3

Secondly, instead of assessing productivity the findings indicate that industry focus on production pace, -disturbance and -waste. By following up active working time, idle times or unnecessary work can be identified and eliminated which, according to the workshop, can be understood as to increase productivity.

> One seldom talks about productivity on site, one can rather talk about pace as in manufacturing. There is a baseline for pace-schedules, but somehow, we do not manage to compare them between projects due to exceptions and external influences. Somehow there is always an excuse to focus on exceptions instead of what is actually produced. - IP 1

> There are measures of disturbance and waste, that is, how much we work and how much disturbance we have. If we decrease disturbances and waste, productivity should increase. - IP 4

The last major challenge evident from the workshop had to do with project type productivity measurements and, again, how costs and unit time is defined. The common ground for production planning is founded on unit time for each task, which is connected to piece rate. The piece rates are often developed from KPIs that are rooted in past and project-based negotiations with labour unions. Even if adjustments based on project leaders experience may be possible, the studied companies do not have full control over piece rates and thus do not normally change the unit times.

> Unit time is based on piece work and negotiated with labour unions. We do not control the time units by ourselves. - IP 1

> "Unit times are often old, from the 60s. - IP 2

From the organization's perspective, they adjust these union negotiated KPIs to fit the company based on strategy reasoning and market situation in procurement and to win contracts but also control task and project costs. This apparently creates a situation where project managers steer towards a project final cost instead of towards productivity improvements.

> Nowadays, one steers towards a final cost. If that is achieved, one seldom do any adjustments. - IP 1

> KPIs are not used for increasing productivity; they are rather used for cutting costs. - IP 4

DISCUSSION

Generally, the findings concur with what literature, e.g., Huang *et al.,* (2009) and Naoum (2016) indicate; that there are different understandings and therefore disagreements related to what productivity is. On the one hand, the economist understand productivity as a number based on gross value-added measures. On the other hand, the IPs understand productivity as progress in work, unrelated to gross-value or prices.

The IP's seemingly argue that single factor productivity leaves out many driving factors of productivity, much in line with observations in Crawford and Vogl (2006). What the studied HB companies seem to ask for are measurements for improving and evaluating their progression and performance in all levels. The CLP measure commonly used on the industry level does not serve for that purpose. Following the reasoning in Crawford and Vogl (2006), TFP could be more appropriate than CLP when looking for improvements in work progress. Results also indicate that measurements and active actions to reduce disturbances and waste are in use by the companies. However, literature does not define waste and disturbance as measurements of productivity. Thus, based on the preferences expressed by the four company representatives in this initial step of the research, the multi-factor TFP method seems to be in favour to incorporate these managerial actions.

The representatives further state that their companies perform task level progression measurements from time to time. However, they also state that there are challenges in comparing productivity between different projects and stakeholders due to exceptions, different ways of booking results, variations in project requirements, changes in regulations, etc. These notions adhere to those presented by Huang *et al.,* (2009).

Fernie *et al.,* (2006) state that KPIs are hard to generalize from one context to another. Still, production planning in Swedish HB is based on unit times from predetermined piece rates developed from KPIs and past negotiations with labour unions. As this is the agreement, the studied companies state that actions to improve work progress or productivity in and between projects to change the frame of the unit times are scarce. Thus, instead of steering projects towards productivity improvements, the companies steer projects towards a planned final cost, which is controlled by using KPIs.

CONCLUSIONS

The findings indicate that productivity as a performance measure is understood and assessed differently depending on the context, level and purpose. There seems to be a conflict between economists on national level and IPs regarding the understanding and interpretation of the broad definition of productivity. Besides, the findings and discussion suggest that the companies find existing measures to be inappropriate for improving what they define as productivity. The studied IPs and economist disagreed on what productivity is and what measurements actually should include and measure. Thus, one next step in the following R&D study will be to reach a common ground on what productivity is and should measure in order to proceed in developing a method for measuring productivity with suitable purposes throughout the levels. Acknowledging this, future research will treat the dilemma of what to take into account or not and how when measuring productivity in HB. Of especial importance will be to understand where one should set the boundaries of the system to measure in order to produce meaningful measures without hampering value-adding activities. Better understanding is needed regarding how one can tackle differences between

projects to enable for assessments and comparisons of progress both in and between HB sub-processes and projects, which will be investigated in future steps. Lastly, recent developments in digitalization and industrialization might have potential in acting as possible facilitators for gathering comparable data. The authors will explore this further in the following R&D study.

From these first findings and discussions, one can conclude that measuring productivity does not seem to be common practice. Even if it is measured on industry-level and for some activities on the task level, it is rarely found on stakeholder and project level.

Tentatively and on a more general level, the results point out that measuring productivity for relevant comparison between industries, tasks, organizations and especially projects is problematic due to different ways of working, conditions and contexts between each HB project.

ACKNOWLEDGEMENTS

The strategic innovation programme Smart Built Environment and the Construction Industry's Organization for Research and Development (SBUF) are gratefully acknowledged for their financial support.

REFERENCES

Atwater, J B, Kannan, V R and Stephens, A A (2008) Cultivating systemic thinking in the next generation of business leaders, *Academy of Management Learning and Education*, 7(**1**), 9-25.

Borcherding, J, Palmeter, S and Jansma, G (1986) *Work Force Management Programs for Increased Productivity and Quality Work*. EEI Construction Committee Spring Meetings.

Bresnen, M and Marshall, N (2001) Understanding the diffusion and application of new management ideas in construction, *Engineering, Construction and Architectural Management*, 8(**5/6**), 335-345.

Bröchner, J (2010) *Effektivitetsmått, Bygginnovationen [Efficiency Measures, Build Innovation]*. (Report from a project of a strategic innovation programme in Sweden entitled Bygginnovationen) Available from http://www.bygginnovationen.se/library/2805/effektivitetsmatt_jan_brochner-170316.pdf [Accessed 15/07/2019].

Bröchner, J and Olofsson, T (2012) Construction productivity measures for innovation projects, *Journal of Construction Engineering and Management*, 138(**5**), 670-677.

Chau, K and Walker, A (1988) The measurement of total factor productivity of the Hong Kong construction industry, *Construction Management and Economics*, 6(**3**), 209-224.

Chew, B W (1988) No-Nonsense guide to Measuring Productivity, *Harvard Business Review*, 66(**1**), 110-115.

Crawford, P and Vogl, B (2006) Measuring productivity in the construction industry, *Building Research and Information*, 34(**3**), 208-219.

Egan, J (1998) *Rethinking Construction - The Report of the Construction Task Force*. London: Crown.

Fernie, S, Leiringer, R and Thorpe, T (2006) Change in construction: A critical perspective, *Building Research and Information*, 34(**2**), 91-103.

Huang, A L, Chapman, R E and Butry, D T (2009) *Metrics and Tools for Measuring Construction Productivity: Technical and Empirical Considerations*. Gaithersburg, MD: National Institute of Standards and Technology.

Naoum, S G (2016) Factors influencing labor productivity on construction sites: A state-of-the-art literature review and a survey, *International Journal of Productivity and Performance Management*, 65(**3**), 401-421.

Tangen, S (2005) Demystifying productivity and performance, *International Journal of Productivity and Performance Management*, 54(**1**), 34-46.

The Economist (2017) The construction industry's productivity problems, *The Economist*, 17 August.

Wang, X, Chen, Y, Liu, B, Shen, Y and Sun, H (2013) A total factor productivity measure for the construction industry and analysis of its spatial difference: A case study in China, *Construction Management and Economics*, 31(**10**), 1059-1071.

Vogl, B and Abdel-Wahab, M (2015) Measuring the construction industry's productivity performance: Critique of international productivity comparisons at industry level, *Journal of Construction Engineering and Management*, 141(**4**).

Yang, H, Yeung, J, Chan, A, Chiang Y H and Chan, D (2010) A critical review of performance measurement in construction, *Journal of Facilities Management*, 8(**4**), 269-284.

STUDYING TIME PRESENCE ON SITE AS AN INDICATOR OF PRODUCTIVE TIME USE BY CONSTRUCTION WORKERS

Ruben Vrijhoef[1]

Faculty of Architecture and the Built Environment, Department of Management in the Built Environment, Delft University of Technology, Julianalaan 134, 2628 BL Delft, The Netherlands

Productivity in construction is relatively low compared to other industries. This is particularly true for labour productivity. Problems that contribute to low labour productivity are often related to unorganised workspace, and inefficient organisation of work, materials and equipment. In terms of time use, site workers spend time on various activities including installing, waiting, walking etc. In lean production terms time use should be value adding and not wasteful or non-value adding. The study reported in this paper has endeavoured to measure the time use and movement applying an automated data system. The case study reflected a limited application to a specific kind of activity, namely doors installation. The study investigated time use and movements based on interviews and on automated detection of workforce. The interviews gave insights in the time build-up of work and value-added time use per day. The automated tracking indicated time intervals and uninterrupted presence of site workers on work locations giving indications of value adding time. The time measurements of the study enable comparison of time use categories of site workers. The study showed the data system calculated the same amounts of productive and value adding time one would expect based on the organisation and characteristics of the work. However, the discussion of the results underlined that the particular characteristics of individual projects and types of team work organisation may well have an impact on productivity levels of workers. More application and comparative studies of projects and further development and extension of the automated data system should be helpful.

Keywords: Automated data capture, labour, productivity, presence, time use

INTRODUCTION

Productivity has been a long existing and much debated topic in construction. The deemed low levels of productivity have been a subject for comparison to other industrial and economic sectors. More recently increasing demand and construction activities in many countries with growing economies have put additional pressure on the issue of productivity.

Previous work in construction management and production research, such as lean construction, have also debated the root causes as well as solutions for improving low productivity. Categorisations of work types in value adding versus non-value adding have often been the basis for assessing productivity. In addition, time intervals of

[1] r.vrijhoef@tudelft.nl

Vrijhoef, R (2019) Studying Time Presence on Site as an Indicator of Productive Time Use by Construction Workers *In:* Gorse, C and Neilson, C J (Eds) *Proceedings of the 35th Annual ARCOM Conference,* 2-4 September 2019, Leeds, UK, Association of Researchers in Construction Management, 204-213.

workers on work locations could be indicators of being able or unable to be productive (i.e. adding value) or either unproductive (i.e. non-value adding) in the available time on a work location. The rationale is that workers need a certain minimum amount of time on one location to be able to perform a task (i.e. uninterrupted presence).

Measurement of labour productivity in construction is a laborious and contextual matter. Productivity figures have therefore often been outdated, not present, disputable in other contexts, not very useful in daily situations, and to improve productivity in practical situations. Automated measurement and data capture of proper parameters on site may be a solution to raise the situational knowledge and awareness needed.

This paper presents a study applying such automated data capture and discussed the appropriateness and usefulness the information about productive and even value adding time use of site workers. The parameters for identifying and measuring the value of workers activities are represented by detecting time spent and uninterrupted presence of workers on work locations compared to total time on site verses time needed for value adding work. This approach to productivity relates to input productivity i.e. efficient time use by workers, rather than output productivity e.g. effectiveness of value delivery to the client. In general, this causes debate about the interpretation of productivity and what approach to productivity is most essential.

Theoretical Background

Previously construction work has been characterized by a high number of non-value-adding or unproductive activities, which results in low productivity (Koskela, 1992). Construction is deemed to be among the least productive industries (Botero *et al.,* 2004). For example, in the United States construction productivity increased between 1966 and 2003 by only 0.78% per year (Forbes, 2010).

There is no agreement about precise definitions of productivity (Yi and Chan, 2013). Various definitions differ in which elements of productivity are included and they differ in what is meant by high or low productivity. Productivity has been defined as the ratio between total input of resources and total output of product. Inputs include the elements labour, materials, equipment. Outputs have been defined in terms of numbers products or levels of turnover produced (Hanna *et al.,* 2005). Other approaches view productivity as "the power of being productive", "efficiency" and "the rate at which goods are produced" (Yi and Chan, 2013). Also, production factors included vary. In the construction industry, the workforce is a dominant production factor, and according to this, construction productivity is largely dependent on human effort and performance and thus labour productivity (Jarkas, 2010).

Variation in workflow influences construction productivity and duration (Chun and Cho, 2015) (figure 1). When there is continuity of workflow, there is a reduction of variation in input resources through continuous work and improvement of productivity and learning effects (Chun and Cho, 2015). Workflow variations thus influence production costs and productivity. This impacts the cost efficiency of construction labour. Construction labour costs typically represent 30% to 50% of the total project costs in most countries (Jarkas, 2010). Therefore, labour productivity is an important target to improve efficiency and performance in construction.

However roughly 40 to 60% of working hours are actually spent on work, and therefore 60 to 40% of working hours would be unproductive (Forbes *et al.,* 2010).

Only about 40% of time spent by workers in a typical workday is value added and more than 50% is wasted (Hanna 2010) (figure 2).

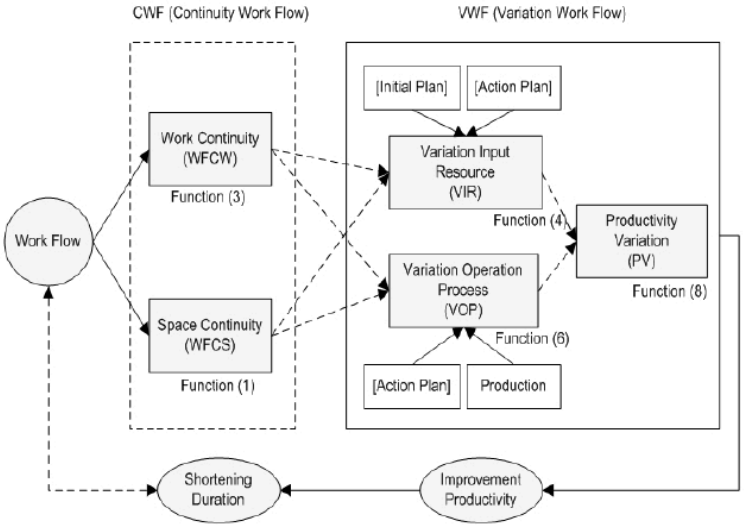


Figure 1: Relation between work flow and productivity variation (Chun and Cho, 2015).

Waste must be regarded as unnecessary costs (Aziz and Hafez, 2013). Waste includes non-value adding activities such as overproduction, waiting and unnecessary transportation and moving (Koskela, 1992).

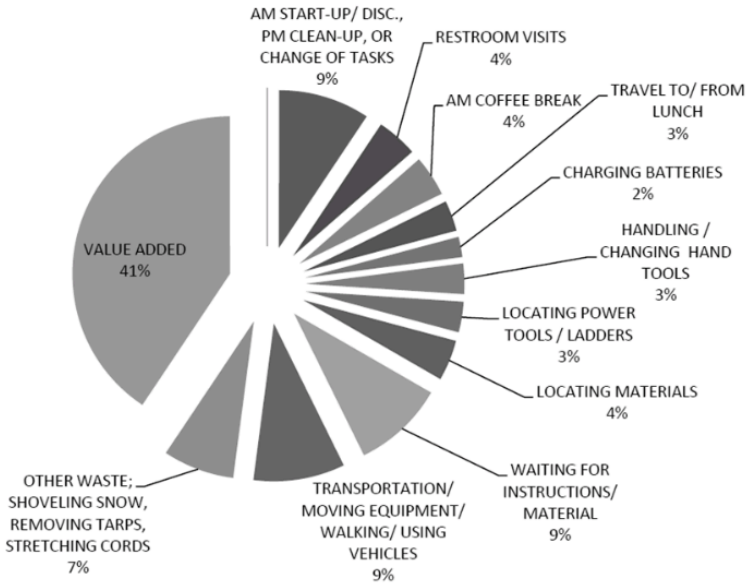


Figure 2: Value-adding versus non-value adding activities in a typical workday (Hanna 2010).

RESEARCH METHOD

The study reported was performed on one site of one firm. The aim was to study the presence of workers, and particularly the uninterrupted presence on work locations. Part of the data collection has been automated via the iCONS system of Aalto University (Seppänen *et al.,* 2019). Next the automated collected data was compared with work description and time build-up of the work via interviews with workers. The comparison between both demonstrated the extent to which automated time presence

measurement could be an indicator of labour productivity in terms of productive time use by site workers.

The automated iCONS system provided the base set of data within the limited case study. The system is in development and tests on various case projects need to demonstrate the functionality of the system. The data system detects and stores data and gives insight in movements and presence of workforce (and materials and equipment) to be able to measure the status of productivity and indicate potentials for improvement measures (figure 3). Further cases are needed to find out what the actual improvement in productivity can be when cases are compared. The study reported is based on a single construction project. The results can be compared and reflected on related to other studies and cases, but not generalised.

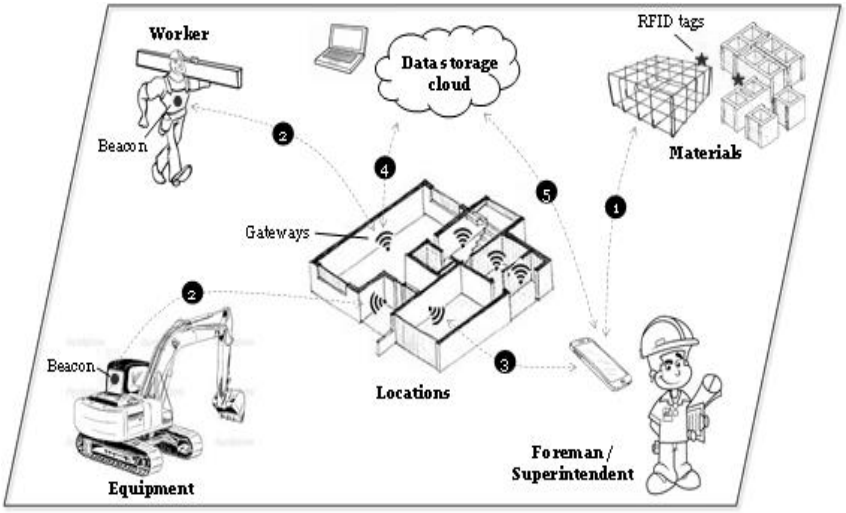


Figure 3: Overview of the iCONS system (Olivieri et al., 2017).

Figure 4: VR representation of the case project.

Case Project

The case used for the data collection within this study is the construction project of 'het Noordgebouw' in the city Utrecht in the Netherlands (figure 4). This is a building of 23,000 m2, accommodating offices, dwellings, retail spaces, a restaurant and a hotel. The project was delivered in December 2018.

Within this case project the iCONS system was applied to collect interval times of presence of workers on work locations in the building. This included two workers of the subcontractor installing the 226 interior doors in the building. The data collection took place to a limited number of 59 doors installed in week 46 to 50 (November 12 to December 11) in 2018.

In addition, the workers were interviewed to derive the logic of the activities of the workers. This logic served to understand, verify and validate the automated data captured as realistic indicators of productive time.

Data Gathering

Data Capture

For the automated data capture 15 gateways with 4G connection were installed in the building and the workers carried Bluetooth Low Energy (BLE) beacons on them in order to be detected by the gateways. For the power supply for the gateways power banks were applied along with a replacement schedule to prevent power issues that would hamper data flow (figure 5).

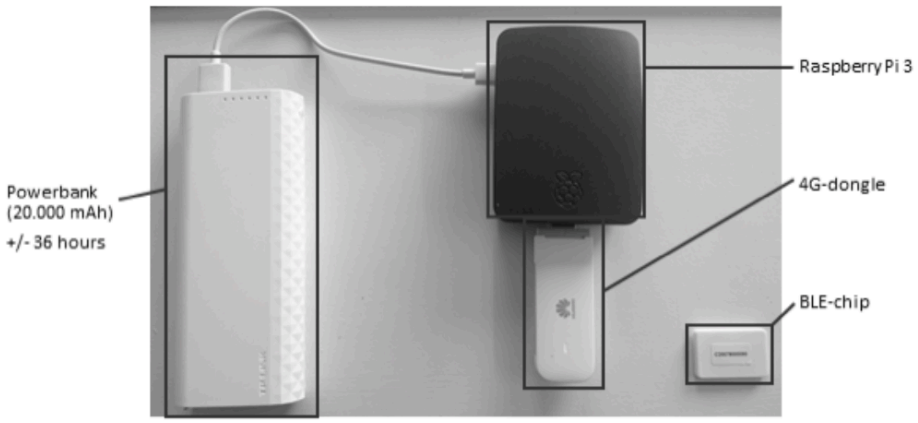


Figure 5. Data capture system incl. BLE beacon, BLE gateway with 4G connection, and power bank.

The gateways were put in place in predefined zones so that the gateway zones collectively covered all movements in the entire building. The floor layout in this case required three gateways per floor. All movements of workers from zone to zone could then be detected from the entering of the building, movements between the floors, movements on floors, and time presence on work locations.

Next the interviews with the workers provided the insights in their work and team organisation and the value adding time merely needed for installing the doors. Installing one door consisted of five standard sub-activities with a minimum of 10 minutes each, and summing up to 60 minutes, equally per door:

- preparing door frame: 15 minutes
- installing and fine-tuning door: 10 minutes
- drilling hole and putting in lock: 15 minutes
- installing and fine-tuning door closer: 10 minutes
- installing door handle and other finishing: 10 minutes

Data Processing

The iCONS system processed the detection data from the beacon real time via the 4G connected gateways to the cloud storage. The iCONS system returned the captured

data of the workers' time spent information via an online dashboard representing the real time detected data.

Further data processing into useful information for further analysis was done manually. This resulted in overviews of spent time intervals per zone and floor. Ultimately the time presence intervals of the two workers on work locations could be concluded.

The interview data enabled to calculate the value adding time per work location based in numbers of doors per work locations, per zone, and per floor.

DATA ANALYSIS

Time Spent on Work Locations

Data heuristics were applied reviewing and improving the automated data. This has led to increased time spent figures, because of typical and specific omissions in the data captured after processing.

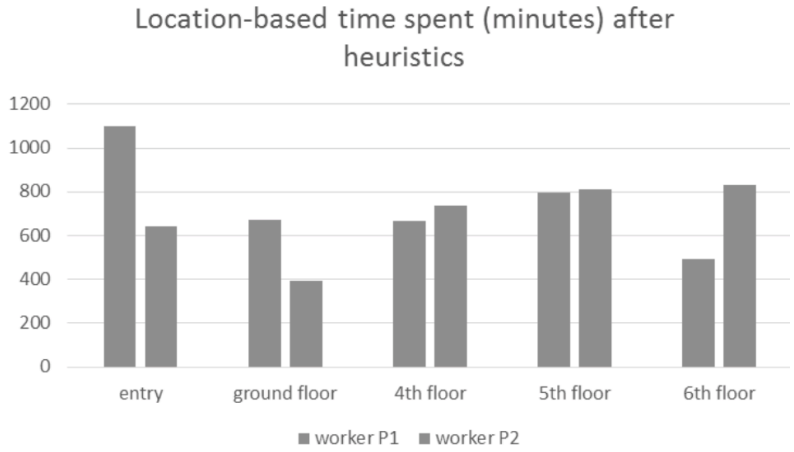


Figure 6: overview of time spent per floor for both workers after heuristics.

Now exact time spent per zone per floor per worker was concluded. In the data we can see the presence for worker P1 and P2 differs per floor. The difference was confirmed by the workers in the interviews, based on the agreed work division amongst them (figure 6):

- Worker P1 mainly worked on lower floors and took care of logistics, and thus spent more time on walking near the building entrance and ground floor.
- Worker P2 mainly worked on higher floors and was particularly focused on installing doors.

Based on the type of activity per floor in the particular weeks, roughly the time spent and movements on the higher floors corresponded to installing doors, so expectedly for larger this would include productive and value adding time. While the time spent and movements on ground level represented mainly logistics and support activities (coordination, transport, walk) which strictly speaking would correspond to unproductive and non-value adding time (table 1).

Table 1: Time spent by workers in building

	P1	P2	Total	Work on floors	Walk etc elsewhere
Entrance	1099	643	1742	-	X
Ground floor	670	395	1065	-	X
Floor 4	666	735	1401	X	-
Floor 5	796	812	1608	X	-
Floor 6	490	833	1323	X	-
Estimate added undetected	600	600	1200	-	X
Total	4321	4018	8339	4332	4007

Time Intervals Per Location

The second data representation for analysis is the divide in 4-time intervals per location. This representation identifies the time spent on work locations for 0-1 minutes, 1-5 minutes, 5-10 minutes, and >10 minutes (figure 7). The figure shows worker P2 has been present for a longer time in work locations and notably more than 10 minutes. This supported the interviews saying worker P2 has been doing most of the installation of doors. While worker P1 has been doing most of the supportive work, including logistics, and being less time on site.

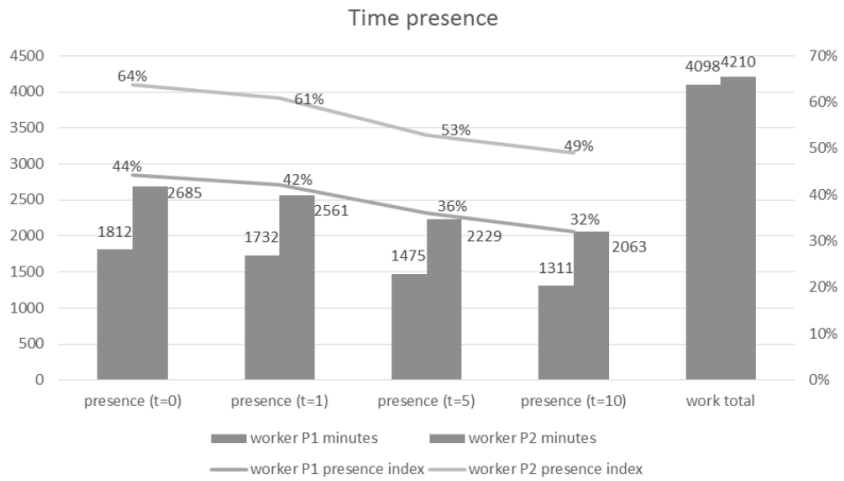


Figure 7: overview of time spent per floor for both workers after heuristics.

Notably the time spent interval of more than 10 minutes is of importance while this is the minimum time needed to be able to execute sub activities of door installation. All sub activities each take 10 minutes or more as mentioned above. The shorter time intervals will likely be walking or other kind of activities, and thus theoretically this represents 'non-productive' work i.e. non-value adding time spent (table 2).

Table 2: Uninterrupted presence of workers in building

	P1 minutes	P1 index	P2 minutes	P2 index	Total minutes
Presence 0-1 mns	1812	44%	2685	64%	4497
Presence 1-5 mns	1732	42%	2561	61%	4293
Presence 5-10 mns	1475	36%	2229	53%	3704
Presence >10 mns	1311	32%	2063	49%	3374
Total	4098		4210		8308

Based on the planning and the interviews with the workers amounts of doors and thus value adding time spent have be calculated (table 3).

Table 3: Value adding time spent by workers on doors installation

	Total doors	Doors in case study	Install Time per door	Install Time per floor
Floor 4	29	18	60	1080
Floor 5	31	21	60	1260
Floor 6	31	20	60	1200
Total	91	59		3540

Based on the above reasoning, if all aggregate time spent by category is compared, time spent for work on floors 4 to 6 takes 52% of total time spent by both workers in the building. Besides time spent on uninterrupted presence of 10 minutes or more (40%) nearly equals the value adding time for installing doors (42%) (table 4).

Table 4: Total time spent by workers per time category

	Location	Minutes	Portion
Total time spent	In building	8339	100%
Time spent on work	On floor 4 to 6	4332	52%
Uninterrupted presence >10 mns	At work location	3374	40%
Value adding time	Installing doors	3540	42%

DISCUSSION

Following the above correlations, one would expect to be able to predict productive time use and thus find indications of productivity in automated data systems as used in this study. However, data reliability is a major issue in this kind of studies. Undefined time spent and potentially undetected time also has influence on the data measurements and thus the data reliability to a certain extent.

Workers attitude to being detected may also cause some level of data unreliability. Workers could regard detection as an unwanted intrusion into their daily routine and this could have an effect on workers behaviour, work and movements. As a result, the motion tracking and thus the productivity assessment could be influenced, in a way comparable to the so-called Hawthorne effect (Mayo 1949).

In the case of this study the data analysis showed that the value adding time of 42% corresponded with the share of uninterrupted presence of 10 minutes and more of 40%. This is in line with the minimum time of 10 minutes needed for respective sub activities of doors installation in this case. This is confirmative while the sub activities generally require uninterrupted presence. The share of 40 to 42% also corresponds with existing productivity studies indicating productive or value adding time use in construction often around this figure, e.g. Hanna (2010) mentions 41%.

One could say the study demonstrated that the assessment of labour productivity correlates to time presence as a variable. To this aim work and tasks have been kept

constant, and a limited and relatively standard type of work has been studied i.e. doors installation. This limits the interpretation and meaning of the study results. Further study would therefore be needed to shed light on the influence of more and other variables, and cases of less standard types of work, potentially leading to deviating results compared to this study.

Based on existing theories this study categorises findings regarding individual work in terms of productive and unproductive. However, in this study and elsewhere teams of workers apply defined and undefined division of roles and activities. For instance, in this study both workers agreed that worker P1 performed supportive activities and worker P2 performed mere installation. Strictly speaking worker P2 would therefore be more value adding than worker P1. However, worker P1 has enables worker P2 to be productive. In this case and elsewhere teamwork and team roles explain and condone one worker being more 'productive' than the other, in case the latter would be performing supportive tasks for the team as a whole.

In the debate around labour productivity in construction the premise is often that all workers need to be equally 'productive'. Although this is ignoring the necessity of having social, logistics and supportive roles in teams, in order to be productive as a team.

CONCLUSION

The study presented has shown that automated detection of time spent, and presence of workers is useful for indicating productive time and value adding time use. Limited application in small environments and low quantities tend to reflect reality and prove to be useful. Wider application in more complex environments will likely need more comprehensive detection methods and data heuristics in order to provide for reliable data.

The case presented included parameters of input productivity i.e. efficient time use in its own right. It is not necessarily reflecting output productivity i.e. effective time use based on output generated. One may assume productive time use per time unit will lead to more production and output. However, indications of increased output and favourable time presence do not necessarily mean that more value is generated by individual team members.

In conclusion, because of the limited case study, more applications and case studies are needed to enlarge data amounts and confirm conclusions in various contexts with different compositions of constants and variables. Also, more work is needed to improve accuracy of the data system and the conversion of time presence data into conclusions about productive time use, and ultimately value adding time use. Finally, the correlations between productive time use, value adding time use, and added value output will need further study.

ACKNOWLEDGEMENTS

The author is thankful for the collaboration with Alto University, the Volker Wessels company, Dura Vermeer company, and the subcontractor for the door installation for their efforts and willingness to be involved and contributing to this study.

REFERENCES

Aziz, R and Hafez, S (2013) Applying lean thinking in construction and performance improvement, *Alexandria Engineering Journal*, 52(**4**), 679-695.

Botero, J, S Djankov, R La Porta, F Lopez-de-Silanes and A Shleifer (2004) The regulation of labor, *Quarterly Journal of Economics*, 119,1339-1382.

Chun, J and Cho, J (2015) Improvement of productivity through the control of continuity and variation of work flow in building space, *Journal of Asian Architecture and Building Engineering*, 14(1), 89-96.

Forbes, L H (2010) *Modern Construction: Lean Project Delivery and Integrated Practices.* London: Taylor and Francis.

Hanna, A S (2010) *Construction Labor Productivity Management and Methods Improvement* ISBN-13: 978-0-9829042-0-6.

Hanna, A, Taylor, C and Sullivan, K (2005) Impact of extended overtime on construction labor productivity, *Journal of Construction Engineering and Management*, 131(**6**), 734-739.

Jarkas, A (2010) Critical investigation into the applicability of the learning curve theory to rebar fixing labor productivity, *Journal of Construction Engineering and Management*, 136(**12**).

Koskela, L (1992) *Application of the New Production Philosophy to Construction*. Stanford University: Center for Integrated Facility Engineering (CIFE)

Mayo, E (1949) *Hawthorne and the Western Electric Company, Public Administration: Concepts and Cases*, 149-158.

Olivieri, H, Seppänen, O and Peltokorpi, A (2017) Real-Time Tracking of Production Control: Requirements and Solutions, *In:* K Walsh, R Sacks, and I Brilakis (Eds.) *25th Annual Conference of the International Group for Lean Construction,* Heraklion, Greece, 9-12 July, 671-678.

Seppänen, O, Zhao, J, Badihi B, Noreikis M, Xiao Y, Jäntti R, Singh V and Peltokorpi (2019) *An Intelligent Construction Site (Icons) Project*, Final Report, Aalto University.

Yi, W and Chan, A P (2013) Critical review of labor productivity research in construction journals, *Journal of Management in Engineering*, 30(**2**), 214-225.

CONSTRUCTION PRODUCTIVITY AND DIGITALISATION: AN IT PRODUCTIVITY PARADOX PERSPECTIVE

Mustafa Selçuk Çıdık[1]

School of the Built Environment and Architecture, London South Bank University, 103 Borough Road, London SE1 0AA, UK

The construction industry has been going through digitalisation for several decades to improve the delivery of built assets. However, despite the ongoing investments in digital technology, productivity growth in construction has remained very low. This suggests that there is a need to better understand the relationship between digitalisation and construction productivity so that the desired productivity benefits through digitalisation could be achieved. A systematic literature review is conducted on the Scopus database to scan the publications that have made claims regarding the relationship between digital technology and construction productivity over the last ten years. The results are grouped into six categories based on the kind of claim they have made, and the key arguments of each group are examined. These key arguments are then discussed using the literature on the 'information technology productivity paradox' as the interpretive framework. The discussion suggests that digitalisation has not had the desired impact on productivity due to the lack of consideration for the interdependencies between various factors and levels of organisation affecting productivity. It is concluded that adopting a system-innovation perspective is crucial to enable meaningful productivity improvements through digitalisation.

Keywords: digital, information technology, productivity, paradox

INTRODUCTION

Over the last few decades, the construction industry has been going through digitalisation to improve the delivery of built assets (Ibem and Laryea 2014). However, productivity growth in construction has remained very low (McKinsey and Company 2017) despite the digital-driven changes in deliverables (RIBA 2013), production and collaboration processes (Shen *et al.,* 2010), as well as professions (Jaradat *et al.,* 2013). Therefore, there is a need to understand the reasons behind the lack of impact of digital technology investments on construction productivity. Such an understanding is key to realising the desired productivity improvement through digitalisation.

This paper draws upon a systematic literature review (SLR) to develop insights into the reasons why digitalisation has not had the desired impact on construction productivity. Considering the limitations of the existing production theory in construction (Koskela and Vrijhoef 2001), the SLR asks the very basic question of 'how does the use of digital technology affect productivity in construction?' to

[1] selcukcidik@gmail.com

Çıdık, M S (2019) Construction Productivity and Digitalisation: An IT Productivity Paradox Perspective *In:* Gorse, C and Neilson, C J (Eds) *Proceedings of the 35th Annual ARCOM Conference,* 2-4 September 2019, Leeds, UK, Association of Researchers in Construction Management, 214-223.

generate insights into the relationship between digitalisation and productivity. Scanning the last ten years of the Scopus database, the SLR captures the papers that have made a claim regarding the relationship between productivity and digital technology in construction, and groups them according to the kind of the claim made. The findings of the SLR are discussed drawing upon the wider literature on the 'information technology (IT) productivity paradox' (Macdonald *et al.,* 2000) to propose potential explanations for the lacking impact of digitalisation on productivity in construction. The discussion suggests that digitalisation efforts fail to adequately consider the interdependencies between various factors and levels of organisation affecting productivity; thus, falling short in delivering the expected productivity improvement. It is concluded that both research and practice need to adopt a system-innovation perspective in order to enable the desired productivity improvement through digitalisation.

The notion of an 'IT productivity paradox' refers to a situation where significant investments in digital technology do not lead to meaningful improvements at aggregate levels of measured productivity (Macdonald et. al. 2000). Although under-explored in construction research, the notion was highly debated in the 1980s and 1990s in economics and management research with regard to the manufacturing and service industries. For this reason, the literature on 'IT productivity paradox' is reviewed in this section to be later used as the interpretive framework for the discussion of the findings of the SLR. The debate on IT productivity paradox can be traced back to Roach's (1987) seminal work which investigated the reasons behind the productivity growth slowdown that started in the 1970s. Significant in Roach's (1987) work was the distinction between an 'information worker' who mainly worked with information using IT, and a 'production worker'. Roach (1987) claimed that information workers were largely responsible for the slowdown by showing that, between 1970 and 1986, information worker productivity had fallen, or grown less than production worker productivity. Roach (1987) concluded that the remarkable increase in computerisation had had very little effect on economic performance, particularly in sectors that involve large numbers of information workers. Baily and Chakrabarti's (1988) work provided further insight into the issue as they suggested that information capital is a driver for employing more information workers rather than a substitute for information workers; hence relative productivity drops. In line with this argument, Osterman (1986) claimed that lower cost of information leads to higher demand, which then leads to an additional demand for information workers.

A decade later, Brynjolfsson and Yang (1996) reviewed the previous work on the IT productivity paradox and warned that the failure to demonstrate a productivity improvement from IT investments might not mean that IT was not contributing to productivity. The authors suggested four possible explanations for the disproportion between the technological progress and productivity growth which, since then, have been widely cited in IT productivity paradox literature. These are 1) mismeasurement of outputs and inputs, 2) lags due to learning and adjustment, 3) redistribution and dissipation of profits, and 4) mismanagement of information and technology. Mismeasurement of outputs and inputs implies that "traditional measures of the relationship between inputs and outputs [may] fail to account for non-traditional sources of value" (Brynjolfsson 1993, p.3). Lags due to learning and adjustment mean that there may be a significant time lapse between cost and benefit of technological progress, which creates productivity puzzles in the short-term (i.e. first decades of technological change) in relation to increasing computerisation. Redistribution and

dissipation of profits account for the idea that "those investing in the technology benefit privately but at the expense of others, so no net benefits show up at the aggregate level" (Brynjolfsson 1993, p.4). Finally, the mismanagement of information technology argument suggests that "we have systematically mismanaged information technology: There is something in its nature that leads firms or industries to invest in it when they shouldn't, to misallocate it, or to use it to create slack instead of productivity" (Brynjolfsson 1993, p.4).

In line with these points, in later works of Brynjolfsson and Hitt (1996; 1998) it was argued that paradox was resolved as they looked at more recent and firm-level data and found correlations between firm-level IT investment and productivity. The clearer correlation between less aggregated productivity data and IT investments suggested that "computerization does not automatically increase productivity, but it is an essential component of a broader system of organizational changes which does increase productivity" (Brynjolfsson and Hitt 1998, p.55). However, despite the cheerful news on the resolution of the paradox in late 1990s and early 2000s, several studies in the literature still claim that the IT productivity paradox has not been resolved, or has merely changed form (e.g. Acemoglu *et al.,* 2014; Hajli and Sims 2015; Van Ark 2016; Polák 2017; Brynjolfsson *et al.,* 2017).

Perhaps the most encompassing discussion of the issue came from Macdonald *et al.,* (2000) who attempted to summarise the debate on the IT productivity paradox. The authors recommended to see the paradox as a matter of innovation, which can be grasped through an analogy between R&D investments and IT investments. According to this, just like R&D investments, IT investments should be seen as a part of the infrastructure required for innovation and competitiveness; and therefore, there cannot be specific calculations of output of IT investments (Macdonald *et al.,* 2000). The authors explained that this perspective would do justice to the extremely complicated issue of the IT productivity paradox, which could not have been resolved with new productivity measurement techniques or generic managerial recipes, such as business process reengineering. Thus, the authors criticised the emphasis on IT-based efficiency improvements by policy-makers and IT developers that advocated ever-increasing use of IT without necessarily understanding the nature of information and importance of innovation. Macdonald *et al.,* (2000) suggested replacing this with an emphasis on IT-based flexibility to promote innovation. They also cautioned against management consultants and fads that mostly neglected that innovation could come in many disguises and sizes depending on the unique circumstances of individual firms.

METHODOLOGY

This research draws upon a systematic literature review (SLR) to generate insights into the reasons why digitalisation has not had the desired impact on productivity in construction. According to Boell and Cecez-Kecmanovic (2015), SLR is a protocol-based approach to literature review which details the steps and processes of searching literature for objectiveness, rigour, replicability, and transparency. SLR is particularly suitable for providing answers to specific questions such as how one variable is related to another (Boell and Cecez-Kecmanovic 2015). Following from this argument and considering the limitations of the existing production theory in construction (Koskela and Vrijhoef 2001), the research question (RQ) for the systematic literature review is set as; 'how does the use of digital technology affect productivity in construction?'. This question enabled the SLR to consider all publications that claimed a relationship between productivity and digital technology in

construction, and the grouping of these publications based on the kind of relationship claimed. Ultimately, such a grouping enables a rich discussion that considers various aspects of the relationship between productivity and digital technology, thus providing fresh insights into the reasons behind the lack of impact of digitalisation on productivity.

The Scopus database was searched for the SLR. The search query string used was "TITLE-ABS-KEY (construction AND (bim OR "building information modelling" OR "building information modeling" OR digital* OR technolog* OR artificial OR "bigdata" OR internet OR online OR web* OR machine OR computer*) AND productivity AND (measur* OR statistic* OR analys* OR increas* OR improv* OR high*))". This search query string returns all articles that include the words 'construction', 'productivity', one of the words relating to a digital technology (i.e. the words listed between 'bim' and 'computer*' in the string above), and one of the words relating to the relationship between productivity and digital technology (i.e. the words listed between 'measur*' and 'high*' in the string above) at the same time. These words were searched in the titles, abstracts and keywords of the articles. Following the initial search, the results were limited to journal articles in English that were published online between 01 January 2010 and 03 April 2019 (i.e. last ten years) due to time and resource limitations of the researcher. The remaining results were then filtered by the subject areas of 'engineering', 'business, management and accounting', 'social sciences', 'computer science', 'economics, econometrics and finance', 'decisions sciences', and 'multidisciplinary' to be made relevant to construction. 625 articles remained after these steps. The initial screening was done on the Scopus's search results page by reading the titles and abstracts of the remaining articles. In line with the RQ, only studies that claimed, and/or referred to, a relationship between digital technology and productivity were included. Papers were excluded if they only looked at the inner production processes of manufacturers in the construction supply chain.

The initial screening reduced the number of studies to be considered down to 130, which were then downloaded to, and managed in, RefWorks. At this point, the papers were grouped as below according to the kind of the claim that they make regarding the relationship between digital technology and productivity. The grouping was done based on a re-reading of the abstracts and main arguments/findings of the papers.

1. Papers that discuss the critical factors for performance and productivity (n= 9)
2. Papers that discuss methods/approaches for productivity/performance measurement (n= 36)
3. Papers about the use of digital technology for productivity monitoring, optimisation, planning and modelling (n= 40)
4. Papers that claim productivity improvement through the use of digital technology but do not engage in any measurement (n= 31)
5. Papers that claim measured productivity improvement through the use of digital technology (n= 10)
6. Papers that study the use of digital technology from a system-innovation point of view to refer to productivity improvements (n= 4)

Following the grouping, the papers were re-examined to identify the key arguments in each group of literature in relation to the RQ. Finally, the groups were paired (i.e. Group 1 and 2; Group 3 and 4; Group 5 and 6) to provide a better overview in the discussion of findings. In the next section, the key arguments identified from each group are first presented in pairs, and then discussed in relation to the IT productivity paradox literature presented earlier in the paper. This generates insights into the

reasons why digitalisation could have failed to improve productivity in construction. Due to space limitations not all the reviewed articles could be included in the following section; and therefore, only the most relevant ones are discussed.

FINDINGS AND DISCUSSION

Papers on factors affecting productivity (Group 1), and measurement of productivity (Group 2)

The studies concerned with factors affecting productivity imply that digital technology has a positive impact on productivity, claiming that areas extensively addressed by digital technology, such as design quality and planning, are critical to productivity (e.g. Jarkas *et al.,* 2015; Naoum 2016). On the other hand, the difficulty of understanding the dynamics of labour productivity, particularly at an aggregate level, are acknowledged, for example, in Yi and Chan (2014), and Naoum (2016). Therefore, the argument is put forward that further critical research is needed to better understand the interplays between various critical productivity factors such as technology, management, innovation and labour composition considering the interdependent levels of task/activity, project, firm and industry (Goodrum *et al.,* 2011; Yi and Chan 2014; Naoum 2016; Pan *et al.,* 2018)

In line with these calls for further research, a few studies in the second group show that growth in Total Factor Productivity, which is regarded as the main driver of labour productivity growth (McKinsey and Company 2017), is affected differently by changes in technological progress, technical efficiency and scale-mix efficiency for different companies/regions/countries (Chiang *et al.,* 2012; Chancellor and Lu 2016; Azman *et al.,* 2019). These studies suggest that in most cases technological progress seems to increase labour productivity (see Kapelko and Abbott 2017 for an exception). However, more interestingly, they also suggest that meaningful productivity increases are possible by increasing technical efficiency and/or adjustments on scale-mix efficiency, depending on the particularities of a company/region/country. Leviäkangas et al.'s (2017) work is relevant here as they observe that the correlation between ICT investments in construction and construction productivity is weak when using industry level data from national accounts.

These arguments resonate with the studies that have suggested developing productivity measures which consider the quality of inputs and outputs, not only to better capture the real contribution of the changes in the industry (Sands 2010; Horta *et al.,* 2010), but also to understand what kind of innovations would have the largest/most disruptive positive impact (Bröchner and Olofsson 2012). Studies that have aimed to capture the productivity losses and gains due to certain organizational, communicational and managerial issues that can be related to IT use can also be seen as part of this effort (e.g. Cheng *et al.,* 2015; Park and Lee 2017). Furthermore, as opposed to the common assumption, Bröchner and Olofsson (2012) stated that, when it comes to innovation, the construction industry has more similarities to service industry than to manufacturing industry. This argument deserves further investigation considering the discontent about the explanatory power of existing productivity measures which hampers innovation in the industry.

Overall, looking at the studies in these groups, it seems like there is an agreement on the importance of technological progress to improve productivity, but also an acknowledgement that technological progress needs to be an enabler for systemic innovation. There is a lack of understanding on what to aim for regarding technological progress due to the lack of understanding regarding the interplays

between various factors contributing to productivity at different levels of organization. This situation raises a red flag as it resonates with the IT productivity paradox literature which warns that when decision-makers in firms did not know what to do with technology, technology developers and management consultants tended to steer the change, leading to unsuccessful technology applications (Macdonald et. al 2000).

Papers on productivity monitoring, optimisation, planning, and modelling (Group 3), and papers claiming unmeasured productivity gains (Group 4)
These two groups cover the biggest number of papers with a total n= 71 (out of n= 130). The findings of the SLR suggest that technologies for task-level and project-level productivity monitoring, optimisation and planning attract significant attention, particularly in the area of earthworks in which automation is widely debated (see Azar and Kamat 2017 for a review). Also, there are several studies on productivity modelling (e.g. Lee *et al.,* 2014; Gerek *et al.,* 2015), which seems to benefit from the increasing processing power of computers. Considering that adequate planning has been identified as a critical productivity factor alongside site management (e.g. Naoum 2016), these studies are supposed to have a positive impact on productivity in practice by also addressing the ongoing challenge of establishing baselines for productivity in construction (Jarkas and Horner 2015; Yi and Chan 2014).

On the other hand, there is a considerable number of articles that claim productivity gains from digital applications that improve various tasks and processes during design and construction. These spread along a wide variety of focus and scope, ranging from the benefits of general concepts, such as using digital applications in construction (Liu *et al.,* 2017), via managerial domains, such as site management using mobile computing technology (Teo *et al.,* 2016), to specific issues, such as design error reduction using BIM (Wong *et al.,* 2018). Like the papers reporting improvements for productivity monitoring, optimisation, planning and modelling, the studies in this group address issues that were previously established as critical for productivity, which is what their claim for 'potential' productivity increase builds on.

With the IT productivity paradox literature in mind, for these two groups of paper, the question becomes whether (and how) the reported improvements addressing individual tasks/functions/domains in construction can actually enable meaningful overall productivity improvements. This is an important question considering Roach's (1987), Baily and Chakrabarti's (1988) and Osterman's (1986) arguments about the nature of information capital and the information worker. It is difficult to disagree with Nath *et al.,* (2015) (from Group 4), who argue that identifying and addressing inefficient points in production are crucial for re-organising processes in a more efficient way with the help of digital technology. However, if the ultimate aim is to improve overall productivity, then perhaps it is time to also start thinking about how digital technology could be used to develop flexibility of production for innovation, instead of creating isolated efficiency improvements that might merely lead to organisational slack, as cautioned by the IT productivity paradox literature (e.g. Brynjolfsson and Yang 1996).

Papers claiming measured productivity benefits (Group 5), and papers studying the use of digital technology from a system-innovation point of view (Group 6)
Similar to the studies discussed in the previous sub-section, papers demonstrating measured productivity improvements also vary in their scope and foci. However, two additional insights seem to be enabled in these studies in terms of (i) the extent to which productivity increased, and (ii) the enablers and barriers of the identified

productivity improvements, which were revealed by putting the proposed solutions into practice (e.g. Zekavat *et al.,* 2015; Yamaura and Muench 2018; Hwang et. al. 2019).

Also, the SLR returned a small number of papers that study the use of digital technology from a system-innovation point of view. Although these studies are lacking the vivid details of the papers claiming measured productivity benefits, the two groups are similar in their conceptual richness. Articles that study the use of digital technology from a system-innovation point of view provide a conceptual picture within which studies that address more specific areas can be interpreted. In this group of papers, while Holmström *et al.,* (2014) study BIM as infrastructure, Aksenova *et al.,* (2018) suggest understanding BIM deployment through an ecosystem lens. Furthermore, Dowsett and Harty's (2018) work, which employs an information systems approach to BIM implementation, considers company-level and project-level aspects of BIM implementation in tandem, thus exposing how focusing on only one of these levels creates a simplified view of BIM leading to unsuccessful results. Finally, although more empirical in its approach, the work of Ahn *et al.,* (2016) also reveals the multiple dimensions that a contractor needs to consider in order to gain meaningful benefits from BIM, thus implying the need for system-innovation.

In line with Macdonald et al.'s (2000) reflections on the IT productivity paradox literature, the papers in these two groups confirm, in a complementary way, that meaningful overall productivity gains from using digital technology depend on the extent of the innovation achieved in the respective (i.e. information, socio-technical, and so on) system. This is also in line with the arguments presented by the studies looking at critical factors of productivity and studies concerned with productivity measurements and trends in the industry (see above). Therefore, the studies reporting measured productivity gains and system-innovation perspectives are likely to help researchers and practitioners refrain from unrealistic expectations from digital technology and drive more realistic innovation agendas to create meaningful productivity gains through digitalisation.

CONCLUSIONS

Despite the increasing number and variety of digital technology in construction, the disheartening results of construction productivity reports have remained the same over the last two decades. Motivated by this phenomenon, this paper has set out to discuss the relationship between digitalisation and construction productivity by drawing upon the insights enabled by the IT productivity paradox literature. An SLR was conducted on the Scopus database, grouping 130 articles into six categories; subsequently, each group was re-examined to explore the effects of digital technology on productivity.

Although this paper is limited in its scope and extent, and thus the arguments made here must be further validated, some interesting points have emerged to generate debate. It is found that articles studying measurement techniques and critical factors for productivity reveal not only issues of mismeasurement, as also highlighted by the IT productivity paradox literature, but also misguidance due to mismeasurement. Also, the present paper has found that there is a major interest in conducting studies focussed on a specific task, function, etc., claiming productivity gains from digital technology without however systematically measuring it. When these two findings are considered together, the concern rises that, at an aggregate-level, digitalisation in construction may not be contributing to productivity as expected. In conclusion, both productivity improvement and digitalisation agendas need to adopt a system-

innovation perspective to adequately consider the system-level implications of digital solutions so that productivity improvements could be enabled at an aggregate-level. This implies the need for more conceptual work relating to production in construction as well as theoretically-informed practical experiments with potential digital solutions.

REFERENCES

Acemoglu, D, Dorn, D, Hanson, G H and Price, B (2014) Return of the Solow paradox? IT, productivity and employment in US manufacturing, *American Economic Review*, 104(**5**), 394-99.

Ahn, Y H, Kwak, Y H and Suk, S J (2015) Contractors' transformation strategies for adopting building information modelling, *Journal of Management in Engineering*, 32(**1**), 05015005.

Aksenova, G, Kiviniemi, A, Kocaturk, T and Lejeune, A (2018) From Finnish AEC knowledge ecosystem to business ecosystem: Lessons learned from the national deployment of BIM, *Construction Management and Economics*, 37(**6**), 1-19.

Azar, E R and Kamat, V R (2017) Earthmoving equipment automation: A review of technical advances and future outlook, Journal of Information Technology in Construction, 22(**13**), 247-65.

Azman, M A, Hon, C K, Skitmore, M, Lee, B L and Xia, B (2019) A meta-frontier method of decomposing long-term construction productivity components and technological gaps at the firm level: Evidence from Malaysia, *Construction Management and Economics*, 37(**2**), 72-88.

Bailey, M N and Chakrabarti, A K (1988) *Innovation and the Productivity Crisis*. Washington: Brookings Institution.

Boell, S K and Cecez-Kecmanovic, D (2015) On being 'systematic' in literature reviews, *Journal of Information Technology*, 30, 161-73.

Bröchner, J and Olofsson, T (2011) Construction productivity measures for innovation projects, *Journal of Construction Engineering and Management*, 138(**5**), 670-77.

Brynjolfsson, E (1993) The productivity paradox of information technology, *Communications of the ACM*, 36(**12**), 66-77.

Brynjolfsson, E and Hitt, L M (1996) Paradox lost? Firm-level evidence on the returns to information systems spending, *Management Science*, 42(**4**), 541-58.

Brynjolfsson, E and Hitt, L M (1998) Beyond the productivity paradox: Computers are the catalyst for bigger changes, *Communications of the ACM*, 41(**8**), 49-55.

Brynjolfsson, E, Rock, D and Syverson, C (2018) Artificial intelligence and the modern productivity paradox: A clash of expectations and statistics *In: A* Agraval, J Gans and A Goldfarb (Eds.) *The Economics of Artificial Intelligence: An Agenda*. London: The University of Chicago Press.

Brynjolfsson, E and Yang, S (1996) Information technology and productivity: A review of the literature. *Advances in Computers*, 43, 179-214.

Chancellor, W and Lu, W (2016) A regional and provincial productivity analysis of the Chinese construction industry: 1995 to 2012. *Journal of Construction Engineering and Management,* 142(**11**), 05016013.

Cheng, M Y, Wibowo, D K, Prayogo, D and Roy, A F (2015) Predicting productivity loss caused by change orders using the evolutionary fuzzy support vector machine inference model, *Journal of Civil Engineering and Management*, 21(**7**), 881-92.

Chiang Y H, Li, J, Choi, T N Y and Man K F (2012) Comparing China mainland and China Hong Kong contractors' productive efficiency: A DEA Malmquist productivity index approach, *Journal of Facilities Management*, 10(**3**), 179-97.

Dowsett, R M and Harty, C F (2018) Assessing the implementation of BIM-An information systems approach, *Construction Management and Economics*.

Gerek, I H, Erdis, E, Mistikoglu, G and Usmen, M (2015) Modelling masonry crew productivity using two artificial neural network techniques, *Journal of Civil Engineering and Management*, 21(**2**), 231-38.

Goodrum, P M, Haas, C T, Caldas, C, Zhai, D, Yeiser, J and Homm, D (2011) Model to predict the impact of a technology on construction productivity, *Journal of Construction Engineering and Management*, 137(**9**), 678-88.

Hajli, M, Sims, J M and Ibragimov, V (2015) Information technology (IT) productivity paradox in the 21st century, I*nternational Journal of Productivity and Performance Management*, 64(**4**), 457-78.

Holmström, J, Singh, V and Främling, K (2014) BIM as infrastructure in a Finnish HVAC actor network: Enabling adoption, reuse and recombination over a building life cycle and between projects, *Journal of Management in Engineering*, 31(**1**), A4014006.

Horta, I M, Camanho, A S and Da Costa, J M (2009) Performance assessment of construction companies integrating key performance indicators and data envelopment analysis, *Journal of Construction Engineering and Management*, 136(**5**), 581-94.

Hwang, B G, Zhao, X and Yang, K W (2018) Effect of BIM on rework in construction projects in Singapore: Status quo, magnitude, impact and strategies, *Journal of Construction Engineering and Management,* 145(**2**), 04018125.

Ibem, E O and Laryea, S (2014) Survey of digital technologies in procurement of construction projects, *Automation in Construction*, 46, 11-21.

Jaradat, S, Whyte, J and Luck, R (2013) Professionalism in digitally-mediated project work, *Building Research and Information*, 41, 51-59.

Jarkas, A M, Al Balushi, R A and Raveendranath, P K (2015) Determinants of construction labour productivity in Oman, *International Journal of Construction Management*, 15(**4**), 332-44.

Jarkas, A M and Horner, R M W (2015) Creating a baseline for labour productivity of reinforced concrete building construction in Kuwait, *Construction Management and Economics*, 33(**8**), 625-39.

Kapelko, M and Abbott, M (2016) Productivity growth and business cycles: Case study of the Spanish construction industry, *Journal of Construction Engineering and Management*, 143(**5**), 05016026.

Koskela, L and Vrijhoef, R (2001) Is the current theory of construction a hindrance to innovation? *Building Research and Information*, 29(**3**), 197-207.

Lee, C, Son, J and Lee, S (2014) A system model for analysing and accumulating construction work crew′ s productivity data using image processing technologies, *Journal of Asian Architecture and Building Engineering*, 13(**3**), 547-54.

Leviäkangas, P, Paik, S M and Moon, S (2017) Keeping up with the pace of digitization: The case of the Australian construction industry, *Technology in Society*, 50, 33-43.

Liu, T, Mbachu, J, Mathrani, A, Jones, B and McDonald, B (2017) The perceived benefits of apps by construction professionals in New Zealand, *Buildings*, 7(**4**), 111.

Macdonald, S, Anderson, P and Kimbel, D (2000) Measurement or management? revisiting the productivity paradox of information technology, *Vierteljahrshefte Zur Wirtschaftsforschung*, 69(**4**), 601-17.

McKinsey and Company (2017) *Reinventing Construction: A Route to Higher Productivity*. McKinsey Global Institute.

Naoum, S G (2016) Factors influencing labor productivity on construction sites: A state-of-the-art literature review and a survey*, International Journal of Productivity and Performance Management*, 65(**3**), 401-21.

Nath, T, Attarzadeh, M, Tiong, R L, Chidambaram, C and Yu, Z (2015) Productivity improvement of precast shop drawings generation through BIM-based process re-engineering, *Automation in Construction*, 54, 54-68.

Osterman, P (1986) The impact of computers on clerks and managers, *Industrial and Labor Relations Review*, 39, 175-86.

Pan, W, Chen, L and Zhan, W (2018) PESTEL analysis of construction productivity enhancement strategies: A case study of three economies, *Journal of Management in Engineering*, 35(**1**), 05018013.

Park, J H and Lee, G (2017) Design coordination strategies in a 2D and BIM mixed-project environment: Social dynamics and productivity, *Building Research and Information*, 45(**6**), 631-48.

Polák, P (2017) The productivity paradox: A meta-analysis, *Information Economics and Policy*, 38, 38-54.

RIBA - Royal Institute of British Architects (2013) *RIBA Plan of Work 2013 - Overview.* London: RIBA.

Roach, S S (1987) *America's Technology Dilemma: A Profile of the Information Economy*. New York: Morgan Stanley.

Sands, M S (2010) Standards and measures-whole-building metrics driving innovation and high-performance. *Lean Construction Journal*, 1-16.

Shen W, Hao Q, Mak H, Neelamkavil J, Xie H, Dickinson J, Thomas R, Pardasani A and Xue H (2010) Systems integration and collaboration in architecture, engineering, construction and facilities management: A review, *Advanced Engineering Informatics*, 24, 196-207.

Teo, A L E, Ofori, G, Tjandra, I K and Kim, H (2016) Design for safety: Theoretical framework of the safety aspect of BIM system to determine the safety index, *Construction Economics and Building*, 16(**4**), 1-18.

Van Ark, B (2016) The productivity paradox of the new digital economy, *International Productivity Monitor*, 31, 3-18.

Wong, J K, Zhou, J X and Chan, A P C (2018) Exploring the linkages between the adoption of BIM and design error reduction, *International Journal of Sustainable Development and Planning*, 13(**1**), 108-20.

Yamaura, J and Muench, S T (2018) Assessing the impacts of mobile technology on public transportation project inspection, *Automation in Construction*, 96, 55-64.

Yi, W and Chan, A P (2014) Critical review of labor productivity research in construction journals, *Journal of Management in Engineering*, 30(**2**), 214-25.

Zekavat, P R, Moon, S and Bernold, L E (2014) Holonic construction management: Unified framework for ICT-supported process control, *Journal of Management in Engineering*, 31(**1**), A4014008.

BUILDING INFORMATION MODELLING

ANALYSIS OF BIM MATURITY LEVEL AMONG AEC FIRMS IN DEVELOPING COUNTRIES: A CASE OF NIGERIA

Solomon Olusola Babatunde[1], Damilola Ekundayo[2] and Adedayo Opeyemi Adekunle[3]

[1&3] *Department of Quantity Surveying, Faculty of Environmental Design and Management, Obafemi Awolowo University, Ile-Ife, Nigeria*

[2] *School of the Built Environment, University of Salford, The Crescent, Salford, M5 4WT, UK*

Although studies on BIM abound, but there is limited empirical study on the current level of BIM maturity among Architectural, Engineering and Construction (AEC) firms, particularly in developing countries. The purpose of this study is to assess and compare the current level of BIM maturity among AEC firms in Nigeria. The study adopted a literature review, a pilot study, and a semi-structured interview. A semi-structured interview was conducted on the selected AEC firms already using BIM. The outcome of a literature review identified four BIM maturity level namely BIM level 0, BIM level 1, BIM level 2 and BIM level 3 with their respective features for each BIM maturity level, which was used to develop a quantitative assessment tool. The quantitative assessment was used as a supporting tool for assessing the current level of BIM maturity among AEC firms and for comparison approach. The results revealed that Architectural firms were positioned on 2.00, which implies that Architectural firms are on BIM Level 2, Quantity Surveying firms were positioned on 1.02, which indicates that Quantity Surveying firms are on BIM Level 1. Structural Engineering firms were placed on 1.56, which connotes that Structural Engineering firms are on BIM Level 1, and Facility Management firms were positioned on 0.50, which signifies that Facility Management firms are on BIM Level 0 (out of four BIM maturity level). This study has both theoretical and practical implications. For instance, the quantitative assessment tool developed in this study would provide a useful guide for improvement by indicating "what" needs to be done by AEC firms to achieve higher BIM maturity levels. Also, this study could be used to benchmark similar future studies. This study has further contributed to the wider body of knowledge of process improvement in the construction industry at large.

Keywords: BIM, developing countries, consulting firms, maturity level, Nigeria

INTRODUCTION

Over the years, the construction industry has been characterized by low productivity, fragmentation and inability to deliver optimum satisfactory projects to its clients when compared with other industries, particularly manufacturing industry (Latham, 1994; Egan, 1998). These reports anticipated for the amalgamated project procedures, suitable working environment, enhanced management and managerial skills, quality-oriented program among others. All of which are evident in Building Information

[1] sobabatunde80@gmail.com

Babatunde, S O, Ekundayo, D and Adekunle, A O (2019) Analysis of BIM Maturity Level among AEC Firms in Developing Countries: A Case of Nigeria *In:* Gorse, C and Neilson, C J (Eds) *Proceedings of the 35th Annual ARCOM Conference,* 2-4 September 2019, Leeds, UK, Association of Researchers in Construction Management, 225-234.

Modeling (BIM). For instance, Newton and Chileshe (2012) argued that BIM adoption is vital to productivity and competitive nature of the construction industry. BIM was developed in order to provide basis for resolving the inefficiencies of the previous Computer Aided Drawing (CAD) by providing a working digital environment that incorporates all information about a building in an electronic file which can be exchange and use by the various project stakeholders (Abdullah and Ibrahim, 2016). An on-line survey on the extent to which construction professionals uses BIM in the United State of America showed that fifty-six percent of the firms used BIM, applied it on fifty percent of their jobs, with just thirty-four percent of the respondents rarely using it (McGraw-Hill, 2010).

The government of the United Kingdom had successfully integrated BIM in the practices of their construction sector, has recorded substantial savings via the usage of BIM and has identified BIM as a relevant "instrument" in assisting the government to accomplish it aim of fifteen to twenty percent savings on project cost (UK BIM Strategy Report, 2012). However, Akerele and Etiene (2016) argued that the Nigerian construction professionals have low level of awareness on the use of BIM. This was corroborated by Alufohai (2012) that the extent of BIM implementation is relatively low in countries where there are no government policies in place to encourage BIM adoption. Although numerous studies have been conducted on BIM in Nigeria, for instance, Olugbenga (2016) evaluated BIM based project in Nigeria. The study identified the benefits of BIM implementation on the on-going Eko Atlantic City project to include geometrics development and structural systems of the city among others. Ede (2014) studied the implementation of BIM software packages on the delivery of a duplex building in Nigeria. The study showed that reasonable cost and time was saved on the project without prejudice to quality. Despite these previous studies, it is evident that there is little or no emphasis on the analysis of BIM maturity level among Architectural, Engineering, and Construction (AEC) firms in Nigeria. In order to fill this knowledge gap, this study attempt to assess the current level of BIM adoption within AEC firms with a view to identifying and comparing BIM implementation maturity level in Nigeria. This study further investigates the specific barriers to BIM adoption by respective AEC firms, particularly architectural firms, Quantity Surveying firms, Structural Engineering firms, and Facility Management firms.

LITERATURE REVIEW

Current State of BIM Adoption in the Nigerian Construction Industry

Onungwa *et al.,* (2017) argued that there is low level of awareness and technical know-how of BIM in Nigeria. This can be linked to lack of adequate BIM training for staffs and personnel(s) and inadequate exposure to BIM concept or both (Abubakar *et al.,* 2014; Onungwa *et al.,* 2017). According to Kori (2015) both firms that are enormous and medium in size are predominantly on the foremost in the adoption of BIM in the Nigerian construction industry whereas, firms that are relatively small in size rarely use it in their practices. Generally, the construction industry in Nigeria is fragmentized, this implies that various construction professionals usually generate project information and manage them individually (Onungwa *et al.,* 2017). Hamma-adama *et al.,* (2017) claimed that architectural, mechanical, electrical and plumbing designs are still prepared using 2D CAD platform with only few, especially Architects using 3D CAD platform basically for visualization or demonstration. Smith and Tardif (2009) argued that if BIM is used merely for presentation, detention of clashes

and visualization, the numerous inherent capabilities it possesses may remain untapped. Hamma-adama *et al.,* (2017) opined that change of behaviour from the traditional method of procurement is necessary. However, change of behaviour to successfully adopt BIM is often difficult as it requires a complete transition of work processes (Hardin and McCool, 2015). Although BIM adoptions and usage in most developed nations are on the increase. However, the extent of BIM adoption in most developing countries such as Nigeria is best described as stagnant (Ibrahim and Bishir, 2012).

BIM Maturity Level

Khoshgoftar and Osman (2009) stated that the different categories that comprises BIM modeling can in relation to excellence is depicted as maturity. This is affirmed by Succar (2010) who identified maturity of BIM to mean quality, duplicability and extent of excellence in the delivery of a BIM model. There is incessant growth in the evaluation of BIM maturity model in which the criterions served as the standard that construction participants and firms seek to achieve (Chen *et al.,* 2012). Azzouz *et al.,* (2018) identified countries with the highest maturity of BIM in an orderly manner to include Spain, Netherlands, Italy, and Germany. Since individual participant has diversified targets of performance and desired outcomes, maturity models should therefore show these targets (Dakhil, 2017). Chen *et al.,* (2012) asserted that the prevailing models for the maturity of BIM have been intended for specific firms, which comprises of contractors, designers among others while others are categorized as general model of maturity for different types of firms.

The current evaluations of models available in literature are meant to ascertain the extent of BIM maturity for firms, projects and participants (Dakhil, 2017). Azzouz *et al.,* (2018) argued that there are numerous factors responsible for the differences in the maturity of BIM across countries in Europe. These factors are institutionalized forces, individual national rules and guideline in various countries but also include socio-technological factors, traditional and social framework as well as construction participants' experiences, nature and magnitude of project, level of sophistication, revenue and building owners' requirement. Bew and Richards (2008) developed BIM maturity model, which described Computer Aided Drawing as Level 0 BIM which connotes the absence of BIM maturity. This level of BIM maturity is also referring to as infant industry (Jayasena and Weddikkara, 2012). BimTalk (2010) stated that BIM level 0 is an unmanaged Computer Aided Design (CAD), within 2D in which data can be exchange manually or electronically. The BIM level 1 is associated with the implementation of intelligence on elementary CAD usage as the entrance into BIM maturity level (Bew *et al.,* 2008). BIM Talk (2010) stated that BIM level 1 is a managed Computer Aided Design (CAD) in either 2 dimensional or 3-dimensional format, which has collaborative tool that provide uniform data platform with a regularized approach to the structure and format of project data. Bimhub (2017) claimed that BIM level 1 features include visualizations and development of building models and it is often referred to as 'lonesome BIM' because the models generated from it cannot be share between construction project stakeholders.

The level 2 BIM also known as 'Pbim' (proprietary BIM) is a managed 3-dimensional platforms which contain project data, but they are usually models generated in isolated form by various construction professionals. However, these different models are combined to form federalized model, but their identity is left intact (Bimhub, 2017). Level 2 BIM tools have a tendency to be applied on design coordination issues but are

rarely utilized for construction processes (Eadie *et al.,* 2015). Also, Bimhub (2017) reported that the remarkable attribute of this level includes the incorporation of data for construction sequencing (4 Dimensional) and cost information (5 Dimensional). BSI (2013) reported that although level 2 BIM is advantageous, a remarkable transition will be experienced when Level 3 BIM is adopted. The design, formation and usage of Level 2 BIM were recognized as a significant step and response, by the United Kingdom government due to the importance of the construction industry to their economy (Ganah *et al.,* 2014). This has been sustained and promoted via the reviewed Government Construction Scheme 2016-2020 and likewise the Construction 2025 scheme (Alwan *et al.,* 2016). The level 3 BIM also known as iBIM (Integrated BIM) is an individual collaborative, internet-enabled, building model which comprises data for construction sequencing (4 Dimensional), cost information (5 Dimensional) and project whole life-cycle information (6 Dimensional) (Bimhub, 2017). Mason and Knott (2016) argued that level 3 BIM will enhance interconnection of electronic design of various building components and at the same time improve networking, services and project delivery.

RESEARCH METHODOLOGY

The study adopted a literature review, a pilot study, and a semi-structured interview. For instance, the outcome of a literature review identified four BIM maturity level namely BIM level 0, BIM level 1, BIM level 2 and BIM level 3 with their respective features for each BIM maturity level, which was used to develop a quantitative assessment tool presented in Table 1.

Table 1: Quantitative assessment tool

	BIM Maturity Level			
	BIM level 0	**BIM level 1**	**BIM level 2**	**BIM level 3**
Brief description of each BIM level	An unmanaged Computer Aided Design (CAD), within 2D in which data can be exchange manually or electronically	A managed Computer Aided Design (CAD) in either 2D or 3D format which has collaborative tool that provide uniform data platform with a regularized approach to the structure and format of project data	A managed 3 dimensional platforms which contain project data, but they are usually models generated in isolated form by various construction professional; however, these different models are combined to form federalized model but their identity is left intact.	An individual collaborative, internet-enabled, building model which comprises data for construction sequencing (4 Dimensional), cost information (5 Dimensional) and project whole life-cycle information (6 Dimensional)
Score				
	1. No Collaboration. 2. 2D CAD drafting only is utilized. 3. Mainly production information. 4. Output via paper or electronic prints or a mixture of both 5. Distribution via paper or electronic prints or a mixture of both	1. Mixture of 3D CAD 2. 2D CAD drafting and production information. 3. CAD standards are managed 4. Electronic sharing of data from CDE. 5. No collaboration between different discipline	1. Collaborative working 2. Requires an information exchange process 3. Capable of being exported to common file format i.e. IFC or COBie 4. Enables interrogative checks 5. All parties use their own 3D CAD on different shared model	1. Full collaboration 2. Single shared project model is used 3. Enables parties to access that same model 4. Enables parties to modify that same model 5. Eliminate the final layer of risk for conflicting information
	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5

As indicated in Table 1, the quantitative assessment was used as a supporting tool for assessing the current level of BIM maturity among the selected AEC firms. The pilot study was conducted to identify the AEC firms adopted BIM in the study area. Prior to this, the total lists of the four selected AEC firms were obtained from their respective professional bodies in Lagos, Nigeria. Hence, the outcome of the pilot study revealed a total of 79 AEC firms already used BIM for their practices. These comprised 41 Architectural firms, 2 Facility Management firms, 25 Quantity Surveying firms, and 11 Structural Engineering firms in the study area. As indicated

in Table 1, within a particular BIM maturity level (i.e. BIM L0-L3), an identified characteristic were provided, which were used as the criteria for the rating of the interview questions with respect to each AEC firm. In this regard, a scale rating 1-5 was developed to rate the extent that selected AEC firms comprised Architectural firms, Facility management firms, Quantity surveying firms, and Structural engineering firms have gone into a particular BIM maturity level they belong. Thereafter, a semi-structured interview was conducted using the quantitative assessment tool for making a general assessment of the current level of BIM maturity of the selected AEC firms and for comparisons approach. This approach is supported by earlier researchers. For instance, Babatunde *et al.,* (2016) quantitatively assessed the current capability maturity levels of both public and private organizations involved in PPP projects in Nigeria. Bay and Skitmore (2006) quantitatively assessed the level of project management maturity in Indonesian companies. Cooke-Davies and Arzymanow (2003) quantitatively assessed the maturity of project management in six different industries. Therefore, the authors of this paper were able to assess the current BIM maturity levels of the selected AEC firms in Nigeria. The results of average total scores for each of the selected AEC firm were presented in Figure 1.

RESULTS AND DISCUSSIONS

Table 2 reveals the background information of the selected AEC firms comprised the category of the firms, major client of the firms, and number of employees in the firms. It can be seen from Table 2 that Architectural firm has the highest percentage among the AEC firms that used BIM followed by Quantity Surveying firms (see Table 2 for more details).

Table 2: Background information of the selected AEC firms

Characteristics	Frequency	Percentage
Firm's category		
Architectural firm	41	51.9
Facility Management Firm	2	2.5
Quantity Surveying firm	25	31.6
Structural Engineering firm	11	13.9
Total	79	100.0
Firm's major client		
Private individuals	38	48.1
Corporate organizations	29	36.7
Government	12	15.2
Total	79	100.0
Firm's employee		
1 to 10	43	54.4
10 to 20	17	21.5
20-50	15	19.0
Above 50	4	5.1
Total	79	100.0

Figure 1 shows the current BIM maturity levels among the selected AEC firms. Figure 1 indicates that Architectural firms were positioned on 2.00, which implies that Architectural firms are on BIM Level 2, followed by Structural Engineering firms were placed on 1.56, which connotes that Structural Engineering firms are on BIM Level 1. Quantity Surveying firms were placed on 1.00, which signifies that Quantity Surveying firms are on BIM Level 1, and Facility Management firms were positioned

on 0.50, which implies that Facility Management firms are on BIM Level 0 (out of four BIM maturity level). These study findings confirmed previous studies. For instance, Alufohai (2012) claimed that Architects have imbibe the adoption of BIM but mainly used it to improve the visual appeal of their presentation. Hamma-adama *et al.,* (2017) asserted that the status of BIM uptake in Nigeria is the predominant usage of 2D and 3D. Olugbenga *et al.,* (2018) found that the status of BIM adoption among construction professionals in Nigeria is at visualization phase.

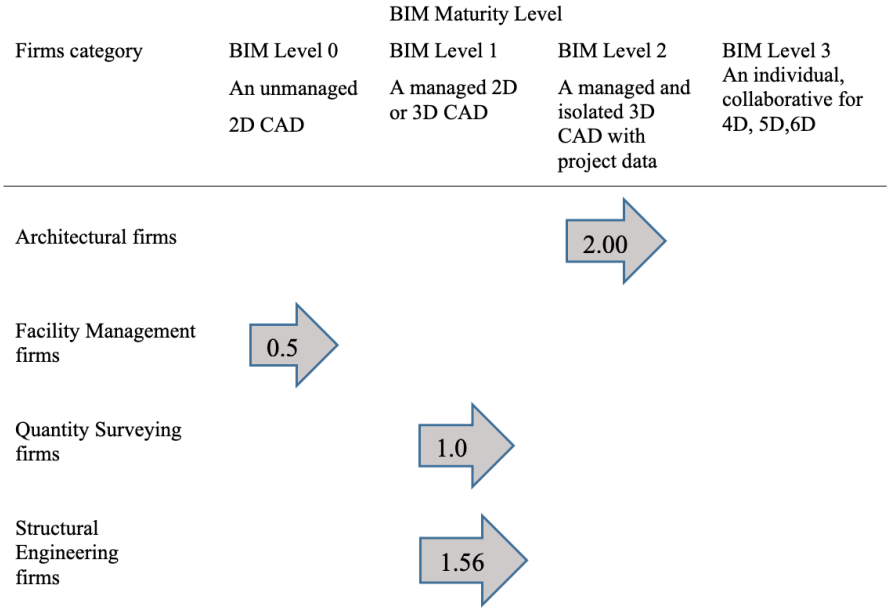


Figure 1: Current BIM maturity levels among AEC firms

Based on the findings in Figure 1, another semi-structured interview was conducted to investigate the factors responsible for the selected AEC firm's respective current BIM maturity levels as showed in Figure 1. In achieving this, 17 AEC firms were purposively selected. These comprised 5 AEC firms each from Architectural firms, Quantity Surveying firms, and Structural Engineering firms, while 2 Facility Management firms were selected. The 17 interviewees across the selected AEC firms were at senior management levels in their respective firms. This approach was supported by Creswell (2009) that researchers could purposively select participants in qualitative research. The questions asked from the interviewees and their compilations of responses, based on each AEC firm category are as follows:

Question 1: *What do you think is responsible for your firm or profession's current level of BIM maturity*?

Architectural firms: The interviewees from the Architectural firms identified BIM awareness, speed and accuracy of doing work with BIM, experience with other consultants, and peers and colleagues deliver similar products as major factors responsible for the Architectural firms to be on BIM Level 2 in Nigeria.

Quantity surveying firms: Majority of the interviewees from quantity surveying firms agreed that low level of awareness and adoption of BIM in Nigeria, BIM involve majorly production of drawings, few stakeholders adopt the BIM, and finances are the prevalent factors responsible for QS firms to be positioned on BIM Level 1.

Structural engineering firms: There is a consensus among the interviewees that BIM awareness is relatively low, and extent of usage is still low as primary factors responsible for the structural engineering firms to be placed on BIM Level 1.

Facility management firms: The interviewees identified lack of demand by clients, and low and inadequate BIM awareness as major factors responsible for facility management firms to be positioned on BIM Level 0.

Question 2: *What do you think is responsible for architectural firms to be on BIM Level 2?*

Architectural firms: The interviewees from the architectural firms agreed that pressure from clients on expected deliverables, experience and exposure, and perhaps they are the first contact with clients particularly in Design-Bid-Build projects are the factors responsible for Architectural firms to be on BIM Level 2.

Quantity surveying firms: The interviewees from the QS firms stated that most architectural firms are on BIM level 2 because they handle the design aspect of construction and majority of the BIM tools available originated for their design usage. However, the other stakeholders are yet to catch up with the architects. Also, early adoption and project initiator/or consultants that first commence the design. Hence, BIM is most useful for them (i.e. architectural firms) on daily basis; therefore, they apply it in their everyday activities.

Structural engineering firms: The interviewees from the structural engineering firms agreed that architectural firms are on BIM level 2 because they are early adopters of BIM compared to other construction professionals in Nigeria. Also, it may be due to their design-oriented activities and the need to improve design quality to impress their clients.

Facility management firms: Majority of the interviewees from facility management firms stated that architectural firms are on BIM level 2, due to basis of their profession, particularly the needs to provide detailed 3D model and visualization to clients.

CONCLUSIONS

This study assessed and compared the current levels of BIM maturity among AEC firms, particularly the Architectural firms, Structural Engineering firms, Quantity Surveying firms, and Facility Management firms in Nigeria. In addition, the study investigated the factors responsible for different current BIM maturity levels exhibited by the selected AEC firms. The study found that Architectural firms were positioned on 2.00, which implies that Architectural firms are on BIM Level 2, Quantity Surveying firms were positioned on 1.02, which indicates that Quantity Surveying firms are on BIM Level 1. Structural Engineering firms were placed on 1.56, which connotes that Structural Engineering firms are on BIM Level 1, and Facility Management firms were positioned on 0.50, which signifies that Facility Management firms are on BIM Level 0 (out of four BIM maturity levels i.e. BIM Level 0 - BIM Level 3). This study established that only architectural firms were on BIM Level 2. This finding is not surprising because the remaining selected AEC firms agreed to the fact that architectural firms are on BIM Level 2, due the pressure from clients on expected deliverables, the need to provide detailed 3D model and visualization to clients, they handle the design aspect of construction and majority of the BIM tools available originated for their design usage, and they are early adopters of BIM

compared to other construction professionals among others. This study has both theoretical and practical implications. For instance, the quantitative assessment tool developed in this study would provide a useful guide for improvement by indicating "what" needs to be done by AEC firms to achieve higher BIM maturity levels. Also, this study could be used to benchmark similar future studies. This study has further contributed to the wider body of knowledge of process improvement in the construction industry at large.

REFERENCES

Abubakar, M, Ibrahim, Y M, Kado, D and Bala, K (2014) Contractors perception of the factors affecting building information modeling (BIM) adoption in the Nigerian construction industry, *In*: *International Conference on Computing in Civil and Building Engineering*, 167-178.

Abdullahi, M and Ibrahim, Y M (2016) Building Information Modeling, Paper presented at A 3 - Day Workshop / *Annual General Meeting of the Nigerian Institute of Quantity Surveyors*, Port Harcourt, 1-50

Akerele, A O and Etiene, M (2016) Assessment of the level of awareness and limitations on the use of building information modelling in Lagos State, *International Journal of Scientific and Research Publications*, 6(**2**), 229-234.

Alufohai, A J (2012) Adoption of building information modeling and Nigeria's quest for project cost management, *In*: *Knowing to Manage the Territory, Protect the Environment and Evaluate the Cultural Heritage*, 6-10th May, Rome, Italy.

Alwan, Z, Jones, P and Holgate, P (2016) Strategic sustainable development in the UK construction industry, through the framework for strategic sustainable development, using Building Information Modelling, *Journal of Cleaner Production*, 140(**1**), 349-358.

Azzouz, A, Hill, P and Papadonikolaki, E (2018) *Which Countries Have the Highest Levels of BIM Adoption in Europ*e? Available from http://www.bimplus.co.uk/people/which-country-most-bim-mature-europe/ [Accessed 12/08/ 2018].

Babatunde, S O, Perera, S and Zhou, L (2016) Methodology for developing capability maturity levels for PPP stakeholder organisations using critical success factors, *Construction Innovation*, 16(**1**), 81-110.

Bay, A F and Skitmore, M (2006) Project management maturity: Some results from Indonesia, *Journal of Building and Construction Management*, 10, 1-5.

BIMhub (2017) *BIM Maturity Level*. Available from https://thebimhub.com/2017/07/14/bim-maturity-level/#.W6TCybMo_qD [Accessed 12/08/2018].

BIMTalk (2010) *Levels of BIM Maturity*. Available from http://bimtalk.co.uk/bim_glossary:level_of_maturity [Accessed 12/08/2018].

Chen, Y, Dib, H and Cox, R F (2012) A Framework for measuring building information modeling maturity in construction projects, *In*: *29th International Conference on Applications of IT in the AEC Industry*, 17-18 October, Beijing, China.

Cooke-Davies, T J and Arzymanow, A (2003) The maturity of project management in different industries: An investigation into variations between project management models, *International Journal of Project Management*, 21(**6**), 471-478.

Creswell, J W (2009) *Research Design: Qualitative, Quantitative and Mixed Methods Approaches*. Thousand Oaks, CA: Sage Publications.

Dakhil, A J (2017) Building Information Modelling (BIM) maturity-benefits assessment relationship framework for UK construction clients. PhD Thesis, University of Salford, UK

Eadie, R, McLernon, T and Patton, A (2015) An investigation into the legal issues relating to Building Information Modelling (BIM), *In*: *Proceedings of RICS COBRA AUBEA*, Sydney, Australia.

Ede, A N (2014) BIM: Case study of a duplex building project in Nigeria, *International Journal of IT, Engineering and Applied Sciences Research*, 3(**4**), 25-28.

Egan, J (1998) *Construction Task Force: Rethinking Construction*. Available from http://www.constructingexcellence.org.uk/download.jsp?&url=/pdf/rethinking%20construction/rethinking_construction_report.pdf [Accessed 04/082018].

Hamma-adama, M, Salman, H S and Kouider, T (2017) Diffusion of innovations: The status of building information modelling uptake in Nigeria, *Journal of Scientific Research and Reports*, 17(**4**), 1-12.

Hardin, B and McCool, D (2015) *BIM and Construction Management: Proven Tools, Methods and Workflows*. Indianapolis, In*:* John Wiley and Sons.

Ibrahim, S and Bishir, I M (2012) Review of using BIM in Nigerian construction industry, *Journal of Environmental Sciences and Policy Evaluation*, 2(**2**), 18-26.

Latham, M (1994) *Constructing the Team, Joint Review of Procurement and Contractual Arrangements in the United Kingdom Construction Industry*. London: HMSO.

Jayasena, H S and Weddikkara, C (2012) Building information modelling for Sri Lankan construction industry, In: *World Construction Conference 2012 - Global Challenges in Construction Industry*, Colombo.

Khoshgoftar, M and Osman, O (2009) Comparison of maturity models, *In*: *2nd IEEE International Conference on Computer Science and Information Technology (ICCSIT)*, Beijing, 297-301.

Latham, M (1994) *The Latham Report: Constructing the Team*, Available from http://www.specify-it.com/CIS/Doc.aspx?AuthCode=&DocNum=84343 [Accessed 04/08/2018].

Mason, J and Knott, M (2016) Is the lack of a common BIM vision between clients and contractors a cause for concern? *Creating Built Environments of New Opportunities*, 1, 673.

McGraw-Hill (2010) *Green BIM: How BIM is Contributing to Green Design and Construction Bedford*, SmartMarket Report, Research and Analysis, Bedford, MA: McGraw-Hill.

Newton, K and Chileshe, N (2012) Awareness, usage and benefits of building information modelling (BIM) adoption - the case of the South Australian construction organisations, *In:* Smith, S D (Ed.) *Proceedings of the 28th Annual ARCOM Conference*, 3-5th September, 2012, Edinburgh, UK, Association of Researchers in Construction Management, 3-12.

Olugboyega, O (2016) Building information modelling-based projects in Nigeria: Evidences from Eko Atlantic City, *Pm World Journal*, V(**X**).

Onungwa, I O, Uduma-Olugu, N and Igwe, J.M (2017) Building information modelling as a construction management tool in Nigeria, W*IT Transactions on the Built Environment*, 169, 25-33.

Succar, B (2009) Building information modelling framework A research and delivery foundation for industry stakeholders, *Automation in Construction*, 18, 357-375.

UK BIM Strategy Report (2012) *Industrial Strategy: Building Information Modelling*, Industrial Strategy: Government and Industry in Partnership, London: HM Government.

EVALUATION OF THE DRIVERS OF BIM IMPLEMENTATION TO SUPPORT THE DELIVERY OF CLIENT REQUIREMENTS (CRS) AMONG THE EARLY BIM ADOPTERS

Farah Shahrin[1] and Chika Udeaja[2]

[1] *Department of Construction Management, Nottingham Trent University, Burton Street, Nottingham, NG7 6HL, UK*

[2] *School of the Built Environment, University of Salford, Room 508d, Maxwell Building, Manchester M4 3WT, UK*

Managing clients and the project constraints to deliver the client requirements (CRs) is a complex process. There are tools, methodology or even theoretical discussion to explore the best solutions to create better dynamics and experience among team members and client, increased value for products and the people and importantly, to change the traditional project delivery processes. In on-going effort to bring in the required innovation, a new dimension of approach is introduced: Building Information Modelling (BIM). However, there is a gap to identify the drivers for BIM implementation for different type of clients across different type of projects among the early adopters. BIM become an important context by providing the collaboration platform to create clearer and visible CRs communication. This part of research sought to evaluate the drivers and its impact project delivery with one BIM champion across three projects. A qualitative inductive research approach was adopted for this study through interviews across three case studies. The first stage research confirms that BIM particularly important creating increased understanding and positive feedback loop among client and facility end user through better visualisation of alternative solutions which is crucial for the efficient iterative design process.

Keywords: champion, client requirements, driver, enabler, innovation

INTRODUCTION

The construction projects are now become ever more competitive as more pressure to create and achieve more value from both sides; the supply (sell) and demand (buy) within quite an uncertainty environment. In 2015, the UK construction industry employing over £2.1mil people or 6.2% of the total UK GDP therefore any positive changes do have impact towards the industry. Digital Britain was set as the target to achieve through smarter construction, better human capability and integration within digital processes (Department of Business, Innovation and Skills,2013). The Building Information Modelling (BIM) was introduced to innovate the traditional project processes (Farmer, 2016): silo, compartmentalised processes, full of surprises as most of the design are finally tested first time on site which normally requires some extra

[1] farah.shahrin@ntu.ac.uk

Shahrin, F and Udeaja, C (2019) Evaluation of the Drivers of Bim Implementation to Support the Delivery of Client Requirements (CRs) among the Early BIM Adopters *In:* Gorse, C and Neilson, C J (Eds) *Proceedings of the 35th Annual ARCOM Conference,* 2-4 September 2019, Leeds, UK, Association of Researchers in Construction Management, 235-244.

re-work, if any issues arise due to unforeseeable problem. BIM methodology on the other hand promoted to managing the project coordinated data throughout the building lifecycle and with its intelligent 3D images which offers better informed decision for the client.

There are many issues associated with the construction projects. The uncertainty over unforeseeable contexts such as management of information across complex networks (Winch, 2002) across different project stages will affect the planning, fluidity of design, error inputting the data, too many participants with varied level of interest for the project and the fragmented processes associated with the project. Not to disregard the further contexts where different type of clients, stakeholders and the suppliers (including the contractors and the project team members) with varying expectations are expected to engage collaboratively to voice their requirement while speaking different 'languages' between the supply and demand. These communication process to communicate the information in a form of needs of client or the Client Requirements (CRs) needs to be clearer and within same wavelength to achieve the project target within the stipulated time and cost and these has been has proven to be challenging. Having BIM in projects not only require aligning current work practices to ensure seamless implementation and having fragmented and temporary nature of organisation (Cherns and Bryant, 1984) with no experience to guide the new work processes and workflows will creates more complexity for the project. With the new working processes and set protocols, it proven can be a challenge to the team without clear implementation vision which affect the participation. BIM does not solve the business challenges such as the clear identification of the deliverables, the protocols of information management among the project team and the participation from the client, especially during design development (Bernstein and Pittman, 2004).

The BIM adoption BIM not only changes the way of working, but the implementation requires a bit more time for effective and successful adoption (Smith and Tardif, 2009) as it requires a process of integrating the technology and the people, as the core of the organisation, to be able to grasp the change (Dawood and Iqbal, 2010). In addition, there is also an issue of managing expectations in BIM adoption which can be less daunting for the client if the client sets a realistic target to achieve (Deutsch, 2011). However, the uptake of BIM is hindered as most of the people in the industry are focussing on the technology (Deutsch, 2011 and Jung and Joo, 2011) rather than also ensuring the people issues relating to BIM are dealt with such as training, continuous learning and maintaining the motivation.

The introduction of BIM in projects pressing demands for the client for more investment such as time and monetary resources to implement the changes. BIM in projects may create another uncertainty and could be view as another project constraints. The golden target in project; time, cost and quality now also include the variables associated with BIM implementation. Various factors such as type of client, time for adoption, varied level of competencies and learning environment may have impact towards the success BIM implementation. Therefore, it is crucial to understand how client and the team manage the challenges to have BIM in their projects by evaluating how the early adopters were moving from Level 1 to Level 2 BIM with various level of BIM understanding and skills. Therefore, this paper aimed to contribute to our understanding how the early adopters managed BIM implementation with the role of BIM champion to facilitate the process.

Managing client requirements (CRs) with BIM: The technology, process and people

The paper formed part of a larger work which aimed to explore and evaluate the challenges during BIM implementation to improve the CRs delivery. To create the understanding of how clients and project team members as the early adopters manage the BIM implementation for their projects, it is also important to evaluate the factors affecting better collaboration between client and team members in communicating CRs with BIM. Ganah *et al.,* (2005) proposed, based on an industry survey, that a new approach is required to accommodate better collaboration of the communication of the design intents and decisions between client and project team. In addition, visualisation along with communication is a powerful approach in ensuring the exchange of design information is clear, well presented and improves client understanding (Ganah *et al.,* 2005). Importantly, the understanding and having good structure for communication of the CRs have effect towards implementation as it unfolds across the contexts as the result of implementation success varies depends upon BIM readiness, capability and the heterogeneity and sizes (Succar and Kassem, 2015).

The distinctness of this study is having the similar approach for BIM implementation driven by the BIM champion who are the main Tier 1 contractor and these 3 different projects were set at stage 2, 3 and 5 of RIBA Plan of Works to create the continuity in the evaluation of challenges of the implementation across the project stages. It is important to note that the clients and team members were at the early stage to understand first-hand the reality and practicality of BIM. None of the participants have any experience with BIM methodology before.

Projects are always competing to balance the need to deliver more value to the client without compromising the quality and the budget set by client and to ensure the supplier within the delivery chain reaps the commercial value out of the project. The driver for BIM adoption needs to be consistent and misalignment between decision for BIM implementation and interorganisational leadership have an effect towards the project outcome (Papadonikolaki, 2018). The traditional role of client has been criticised being fragmented and the industry should focus for more integration and delivering value to the client and project (Egan, 1998). Being uncertain and the temporary nature of project combined with complex structure of client and the organisation (Cherns and Bryant, 1984) does requires more transparent and collaborative platform to support better CRs communication. requires the different participants within the project to share information, expertise and ideas which can benefit from implementation of better management of communication channels, such as the computers that design information can be effectively shared and distributed to avoid any conflicts and clashes (Chiu,2002). However, BIM implementation may change the dynamics of the CRs communication process which in turns affect the collaboration as clients and their networks may have set different vision for the implementation which essentially needs to be compatible to enable the collaboration and success for the projects. Having same vision and level of motivation for the BIM implementation is important to ensure the project participants including the client are engage with the changes.

The UK mandate to improve and digitalised construction industry by having BIM in its construction projects has received mixed reaction. *BIM implementation application, in terms of ensuring a better delivery of the client's requirements (CRs)*

among the first adopters has not been much examined, particularly how BIM assisting client and project teams to understand the processes for BIM implementations to incorporate new way of working and new processes to manage and communicate the information. Less uncertainty in project which contributes to the issues such as misinterpretation, uncoordinated information resulted in error and delays, informed decision by client based on increased engagement along the process (Farmer,2016). Whilst the complexity of BIM always divided into three main components: technology, people and process, this paper discusses all these components interchangeably by focussing to answer the research question for this paper: How do the drivers for BIM implementation in projects have effects on the clients and project team members during BIM implementation whilst coping with varied level of skills and knowledge to deliver the project?

METHODOLOGY AND METHODS

Qualitative through the Interpretivism philosophy inductive nature research was chosen as to best reflect the nature of the investigated phenomenon as to understand how CRs were delivered within BIM environment to improve the communication process among clients and project team. This paper draws upon research conducted as part of the main study which was to explore the delivery of CRs in projects that employed BIM and to investigate whether BIM may improve the process of delivering CRs. The chosen research philosophy allows identification of different views from the practitioners who dealt people who is working and have experience handling client requirement and people that using BIM in their project regarding their professional opinions, ideas and conception on the effectiveness and efficiency of each process, any advantages or limitation that the research participant experienced during the process. Therefore, this research regarded that the assumption of the research participant is subjectively measures, value laden by the research participants experience and their value to construct their ideas or opinion. Interviews through three case studies- a) children mental health hospital, b) a university expansion project and c) adult mental health hospital and all projects are in the UK and delivered through the design and build procurement. It is important to acknowledge that all the case study projects were delivered by the same Tier 1 main contractor who is leading the BIM adoption process - the BIM champion. There are not many cases in which the projects shared the same BIM champion from the same organisation. This is not arbitrary intention, but it is purposely decided that the BIM champion from the same organisation will provide the same support and assistance which allow researcher to better understand how client and project team member react and response towards the assistance and support depending on each individual context. In this study, the context for each of the projects which is the cases were selected based on the uniqueness and the special sense of providing insights which other projects would not be able to provide. The rational for the multiple case studies to provide the longitudinal element over the project as each one of the projects was at the beginning of the project, at the middle of the project and towards the end of the project stages (refer table 1).

Seventeen interviews were employed as the research inquiry through the case study were recorded and transcribed. The output from the case study interviews was based on thematic analysis of the within and across the cases to produce themes, concept and codes based on data display, data reduction and concluding or verification (Miles and Huberman, 1994). The analysis also reviewed and compared against the literature to produce further interpretations and conclusions. The purposive sampling of

interviews aimed to allow each case study data to contain at least the client, the project leader, the architect, the design manager and the BIM engineer as these group of professionals plays important role in managing CRs delivery and BIM processes in the project. Purposive sampling allows each of the unit of analysis- each case study to produce data that encapsulate the experience that were shared from both perspective of project- the supply which was from the client and the supply team- which includes the project team member and the contractor representatives to enhance the characteristic of the chosen case study (Bryman, 2012).

Table 1: Details of case studies (all projects delivered by same contractor who championed the BIM implementation process)

	Project 1 Adult Mental Health Facility	Project 2 University expansion project	Project 3 Children mental health facility
Stage of project during data collection	Stage 1 RIBA	Stage 3 RIBA	Stage 5 RIBA
No of respondents	5	8	4
Details of respondents	Client's project manager, architect, design manager, project leader, BIM engineer	Client's project manager, project leader, design manager, architect, concept architect, BIM engineer, structural engineer and M&E engineer	Client's project manager, design manager, architect and structural engineer

CASE STUDY FINDINGS AND DISCUSSION

The BIM implementation occurred across three case studies through design and build procurement. Broadly, the client from each case study have varied BIM capabilities. Based on interview notes and transcripts, the findings and discussion categorised into the sub-sections.

BIM adoption drivers across the projects and the heterogeneity of project team members

Analysis revealed that BIM implementation across all projects were driven by the external driver- the market or client demand. Further evaluation shown that it was clear that the implementation was requirement by the client driven or the market demand. For example, in project 1, the client proposed to advance the usage of BIM at the earlier stage of the project to gain a better-informed response from the ward management and clinicians. Particularly, the client explained that "*we lost the opportunity to improve communication with the clinicians and because BIM was introduced too late".* This decision has impact on the project stakeholders. This indicates that the client described the intention to have earlier communication with the stakeholders assist the client team to develop better understanding in the process of developing the business case.

The value towards the implementation also quite differ across the projects. One of the clients indicated as the cost and time should be considered as investment in the longer term. *"The outcome has to be the quality because it will be in use for 30 to 50 years and the quality means everything. The cost might be a little bit more and so is the time but so what?* Quality was no longer seen as quality of the product but the ability to show the organisation the capability to satisfy the organisation's needs, which in this case was to ensure the design delivered positive outcomes for patients. The client embraced the change brought about by BIM by proposing BIM as a change agent to

improve construction. However, another client seen this implementation as one of tool rather as a process for improved project delivery. The client mentioned *"we don't have to call it BIM, but it is a basic term for a management tool."*

However, there was misalignment between the motivation and the BIM readiness in Project 2. The project client viewed BIM as another tool for visualisation. According to the client's architect "It depends on what you mean by bringing the BIM process. If it means creating the model earlier on, I can't see any differences as you see their sketch-up because at that stage of the job, you're modelling stuff and you're throwing things away". The client's architect confronted the idea of the BIM implementation thus it created negative effect towards the communication process along the actors in project 2. In this particular project, BIM implementation was started at level 3 RIBA Plan of Work and most of design were developed in 3D non- collaborative packages, therefore, those design were completed before being translated into Revit packages. There was less stable implementation in this project as one party outsourcing the BIM services which impaired the network of communication as any issues with design and the information about the models have be to through with the outsourced organisation. As stated by the mechanical engineer "we don't have any resources and time allocation to learn new skills for this project". This shown that heterogenous decisions about approaching the implementation have effect towards other participants in the project as all enquiries in relation to mechanical issues must be through the outsourced organisation. Further investigation revealed that the vision for client to have the implementation was to meet the market demand and those vision not smoothly communicated across the team members.

In project 3, the implementation was driven by the client. The client really values the BIM processes and engaged throughout the process. The client explained *" So, you tried to refine it all the way, but it is in critical stage trying to communicate what the building look like or feels like at this stage and the more tools that we have ,3D visuals, mock ups the better it is".* The client and their team approached the BIM implementation run smoothly although the implementation started at stage 5 of RIBA Plan of Work.

The heterogeneity of skills and knowledge among project team members with different BIM implementation vision unfolded in many ways. Inconsistencies with BIM approaches although with one BIM champion shown the inconsistent behaviours during the implementation. Project where the visions were not well diffused displayed confrontational approaches which requires more persuasion its members and supply chain to use BIM consistently. According to one of the structural engineers in project 2, *"It's a difficult one. I don't think that is a wasted effort. It is just not efficient effort. […] [long silence] it is difficult to get the right time to start BIM"* which displayed there was inconsistent and incompatible motivation for having BIM. The implementation seen as an ad-hoc decision from the client and lacked support exacerbated the complexity of the project. On the other hands, more emphasis towards the type of client and their impact towards the project participation was stated by one of the architects for project 1. "*It is good to identify the type of client before the start of the project since there are different types of clients in the market".* Client from project 3 seconded the opinion on the client type and relate towards the having the same vision of BIM implementation is important for the project. The client explained *" Well, this is excuses that you get in construction and that sort of embedded in it. But you never hear it from a car manufacturing. […]".* The client was trying to change the mindset of the project team members by comparing with

other industry which is more client-focussed. However, these visions were not supported by clear formal or informal structures nor shared across the rest of the project team.

Contrariwise, the lack of practical experience has driven client in Project 3 to be more positive by setting up plans for improvement. The client project manager took self-initiatives to learn how to manage BIM as stated "*I will say that they could have done a bit more with the client I think on that one, we could have a bit more training as generally I was learning myself on it. I have a little bit training on it, but I learnt myself"*. More investment for training and time should have been planned to improve the experience. As the result, the client's project manager had acquired the required skills and knowledge to manage BIM within their project to function more competently. More importantly, the client and project teams gained more confidence to conduct and deliver the project with BIM.

The data analysis for the drivers for BIM implementation for the early adopters revealed that although the implementation of BIM for all projects were driven by client; however, the visions of having BIM for the client were driven by different motivations. First, the decision to implement BIM pertained to the improvement towards managing information structure and the end-user's expectations. Secondly, market demand pushed the clients to implement BIM for the projects and this demand become a short-term vision as there was no long-term preparation factored into their motivation.

Impact of implementation towards technological-based issues in relation to knowledge mobility

Issues related to technological aspects which reflected the readiness for the clients and project team members to provide the facility required for the implementation. Data analysis revealed that there were few factors hindering implementation across the firms. First, updated technologies and reluctance to conform and to comply with the open standards for information exchanges which become main obstacles among project team members to collaborate effectively. technologies and reluctance to apply or conform to open standard for information exchanges: BIM supposed to be applied across project lifecycle and the data standard such as IFC schemas and COBIe were unknown and access to the common data environment were limited to the project respondents. The client project manager indicated *"He doesn't access A-site, so he wouldn't be aware what the BIM model can do. So, when he must make decision on client, he actually asking for the hard copies for 2D." This shown that the client and* some respondents were unable to conform to such requirement due to lacked support from the top management. The computer system for the client organization required some improvement. Although all projects have the same BIM champion, the practices towards BIM implementation. Secondly, non-compliance with the set protocols. All projects were set at the beginning of the implementation to work within level 2 BIM. But further examination of the data revealed that only limited part of the data was shared and exchanged on the provided platform. Most of the data were shared on the Common Data Environment (CDE) and managed by the main contractor who was the BIM champion for all these projects. All respondents reported to work on federated models of the digital visualization further investigation revealed that the models were uploaded for clash detection exercise. Those models were not utilised towards its better potential such as data interrogation and manipulation for design evaluation. The role of BIM champion for these projects was to act as the knowledge mobility for

the projects by providing on-site training, setting up the required protocols with flexible hands-on demonstration approaches which offers the formal and informal communication process for learning for the project participants. For the BIM champion who was the main contractor, BIM not only managing the information, but BIM acts as the collaboration platform to manage various party expectations. According to the contractor *" The starting point is the concept. To handle the building, it is managing expectations. And the key thing for the model is managing that, because you see it all the way through. You have 2D drawing which hasn't change. I think that is the advantage if you see it and I think it is a great tool of managing expectations". The above statement shown that BIM not only manage the information of the projects, but BIM also act as a good communication channel and this will have effect towards more certainty and stability of project.*

Other factors such as time frame plays important roles towards the implementation. Limited time frame included for the implementation affect the motivation towards the process. According to the concept architect in project 2 *"this is the difficult part of the process because there were so many departments. It was literally down to, as I said had to arrange meeting with and getting group of 10-15 people in a room".* The concept architect was trying to organise clear communication process however lacked support in a top-down manner from the client to support such changes in the way of working. However, better leadership for consistent implementation much obvious in Project 1. The support towards the implementation much more organised in top-down approach. As evidence, client in Project 1 *"Whilst with BIM, it's so much [more] sophisticated and complicated, it takes a little bit longer. So, I think maybe, it will be better, to be allowed bit of more time to develop the information at earlier stage."* The visions of having BIM in projects requires support through formal structures such as training, role of BIM champion including regular meetings and informal structures such as telephone conversation to support any issue issues during the implementation. However, support from top-down approach create positive effect towards heterogeneity of the decisions to implement BIM in the projects.

The data analysis revealed that each BIM implementation across these projects were unique. Not all key features for BIM functionalities were implemented similarly across the projects. For example, model checking tools were implemented as a standardised way across the projects as it was structured and managed by the BIM champion. However, BIM implementation in relation to the use of common data environment and the protocols were depended on the motivation of the project members. Most projects which were positively driven by the implementation adhered to the process and the protocols contrarily with less enthusiast project team members where the implementation requires persuasion to conform due to disparate approaches and no clear vision.

CONCLUSIONS

This research was set out to explore and evaluate the drivers for BIM implementation in projects have effects on the clients and project team members with varied level of skills and knowledge to deliver the project. After the analysis of three projects, the empirical data displayed interdependence between BIM drivers, level of skills and knowledge gained during the implementation and the impact towards project delivery. Essentially, project 2 which featured organisation with misalignment of motivation of implementation, was more rigid and less flexible towards attempting approaches for implementation. This resulted in hindered knowledge transfer. Contrariwise, Project

1 and Project 3 have better consistent project outcome with positive, keener to engage with the implementations. This inconsistencies with overall outcome and the approaches towards the implementation revealed that although knowledge mobility for the implementation was facilitated by the BIM champion, the compatible vision for implementation creates more collaborative working which promote dynamics of the projects. The knowledge silo disrupted the organisational knowledge among the team members for project 2.

Moreover, open communicative environment encourages the collaboration platform during the project process were acknowledge across the client and team members although some do have less appreciation towards the potential of BIM can offer. The arranged and coordinated client participation would eventually improve the client commitment to BIM implementation. Structured training and minimum knowledge level to achieve knowledge for client and team members should have been developed to ensure the client and project team competencies and readiness with BIM are more consistent and ultimately creates more value added to the BIM implementation. This structured training will further determine the type of client/team members which will be useful in identifying the suitability of skills during team formation. Support and leadership as the top-down approach is one of the essential elements for consistent BIM implementation. Across these case studies, all clients are experienced client as the client has several projects and a team with sound knowledge and skills in construction projects. Having analysed this small part of the research components, it can be concluded that misalignment of drivers for implementation have direct effects towards the implementation. Varied level of knowledge and skills exacerbated the implementation process however with consistent approach from the champion would assist for smooth communication and learning and knowledge seeking process.

REFERENCES

Bernstein P and Pittman J (2004) *Barriers to the Adoption of Building Information Modeling in the Building Industry Autodesk Building Solutions*, White Paper.

Bryman A (2012) *Social Research Methods*. Oxford, Oxford University Press.

Chiu M.-L (2002) An organizational view of design communication in design collaboration, *Design Studies*, 23(**2**), 187-210.

Crilly N, Good D, Matravers, D and Clarkson P J (2008) Design as communication: exploring the validity and utility of relating intention to interpretation, *Design Studies*, 29, 425-457.

Dawood, N and Iqbal, N (2009) Building Information Modelling: Scope for innovation for the AEC industry. *In*: *Proceedings of the 10th International Conference of Construction Application of Virtual Reality, Second International Conference on Post-Disaster Reconstruction: Planning for Reconstruction*, 4-5 November 2009, Sendai, Japan.

Department for Business, Innovation and Skills (2013) *Construction 2025*. London: Department for Business, Innovation and Skills.

Department of Business, Innovation and Skills (BIS) (2011) *A Report for the Government Construction Client Group Building Information Modelling (BIM) Working Party Strategy Paper*, London: Constructing Excellence/BIS.

Deutsch, R (2011) *BIM and Integrated Design: Strategies for Architectural Practice*. Hoboken, N.J, Wiley.

Ganah, A A, Bouchlaghem, N B and Anumba, C J (2005) VISCON: Computer visualisation support for constructability, *ITCon*, 10, 69-83.

Jung, Y and Joo, M (2011) Building information modelling (BIM) framework for practical implementation, *Automation in Construction*, 20, 126-133.

Papadonikolaki, E (2018) Loosely coupled systems of innovation: Aligning BIM adoption with implementation, *Dutch Construction Journal of Management Engineering*, 34(**6**).

Pietroforte, R (1997) Communication and governance in the building process, *Construction Management and Economics,* 15(**1**), 71-82.

Royal Institution of British Architects (1997) *Plan of Work for Design Team Operation*. London, RIBA Publications Ltd.

Smith, D K and Tardif, M (2009) *Building Information Modeling a Strategic Implementation Guide for Architects, Engineers, Constructors and Real Estate Asset Managers*. Hoboken, N.J, Wiley.

Succar, B and Kassem, M (2015) Micro-BIM adoption: Conceptual structures, *Automation in Construction*, 57, 64-79.

Winch (2002) *Managing Construction Projects*. Oxford, UK: Blackwell Science.

INTEGRATING CMMS, EXPERT SYSTEMS AND BIM FOR IBS BUILDING MAINTENANCE

Zul-Atfi Ismail[1] and Ibrahim Motawa[2]

[1] *Universiti Malaysia Perlis (UniMAP), School of Environmental Engineering, Kompleks Pusat Pengajian Jejawi 3, Arau, Perlis, 02600, Malaysia*

[2] *Department of Architecture, University of Strathclyde, 75 Montrose Street, Glasgow, G1 1XJ, UK*

Current methods of maintenance management have affected the efficiency of the relevant tasks when applied to the industrialised building system (IBS) for high-rises in Malaysia. Many issues, such as poor service delivery, limited budgets, incompetent staff and defect repetition, have emerged from the use of conventional methods of application (paper-based forms). A total of 73.5% of IBS building maintenance tasks in Malaysia feature the conventional method. Data have revealed that the practice of maintenance management for IBS high-rise buildings needs to be digitalised. Therefore, this paper reviews current practices in maintenance management and develops a Building Information Modelling (BIM) prototype system that addresses problems with to the conventional method to improve the processes of maintenance management. This qualitative research was carried out by conducting a literature review and semi-structured interviews. Eight major maintenance organisations were selected based on the conventional method of practice in managing maintenance for IBS high-rise buildings. The framework was represented in a computer-based prototype system in Autodesk Revit to allow multidisciplinary information to be superimposed onto a digital building model, Microsoft Visual Basic.Net was used as graphical-user interface while Microsoft Access was used for database design to deploy information on maintenance management processes. The computerised system was developed using data flow diagrams and coding. The prototype system was then tested, and the results show that it makes defect diagnosis and decision-making process easier, faster, and cost effective while facilitating the assessment of maintenance, defect diagnosis, and control in relation to components of IBS building structures. In conclusion, the prototype system can improve the effectiveness of maintenance management practices for components of the IBS building structure by reducing the risk of defects in design, such as the design calculation error, to provide high-quality components for the structure to ensure a safe and healthy environment.

Keywords: BIM, IBS Building, maintenance, decision making, diagnosis

INTRODUCTION

Building maintenance is poorly managed in construction projects that employ the industrialised building system (IBS). According to Kamar *et al.,* (2012) and Mohamad *et al.,* (2016), aesthetic and structural defects occur more frequently in components of buildings constructed using IBS than those of conventional buildings. Such problems as a lack of integration among maintenance systems, lack of

[1] zulatfippkas@gmail.com

Ismail, Z-A and Motawa, I (2019) Integrating CMMS, Expert Systems and BIM for IBS Building Maintenance *In:* Gorse, C and Neilson, C J (Eds) *Proceedings of the 35th Annual ARCOM Conference,* 2-4 September 2019, Leeds, UK, Association of Researchers in Construction Management, 245-254.

coordination between design and construction, insufficient consideration of defect diagnosis in the decision making process, and the absence of a link between operations of defect diagnosis in maintenance that affect various elements of the building and knowledge of defects in components of IBS, have led to significant problems in the maintenance management of IBS buildings. The absence of standard tools of diagnosis and guidelines for prefabricated components contributes to additional cost to redesign the project when measuring the maintenance delivery in IBS construction. This leads to an increase in maintenance and operation costs, including the time taken for construction, and production and labour costs (Yunus and Yang, 2012; Chang and Tsai, 2013). A limited systematic process of decision-making owing to the lack of integration among team members when dealing with risk management in IBS construction projects is also problematic for maintenance management. There is no best method for problem solving and decision making under these circumstances (such as difficulties in maintenance planning, and insufficient knowledge of building materials and requirements of the maintenance of components) (Zakaria *et al.,* 2012; Chiu and Lin, 2014).

Most prevalent process of maintenance management use conventional methods, with little emphasis on decision making and tool of defect diagnosis. In conventional methods, all design and construction processes are conducted in a sequential manner to provide maintenance teams assessing building degradation the choice of optimal maintenance strategies for components or materials in IBS buildings with the minimal lifecycle analysis of projects (e.g. requirements, and operational and maintenance-related information) (Ismail, 2014; Nawi *et al.,* 2014a). The use of ICT technology in the construction industry is now commonplace for facilitating various maintenance-related activities (failure analysis, documentation of maintenance, fault location, repair, and reconstruction). An example of the use of ICT is the bottleneck of massive data between maintenance components and building management, which can now be eliminated by converting raw data on the quality of systems and their process capability into knowledge for dynamic decision making (Ruiz *et al.,* 2013; Kamsu-Foguem and Noyes, 2013). A few researchers have considered IBS to provide more efficient decision support tools for diagnosis, such as the PPMOF (Prefabrication, Preassembly, Modularisation, and Offsite Fabrication), IMMPREST (Interactive Method for Measuring PRE-assembly and Standardisation), PSSM (Prefabrication Strategy Selection Method), and CMSM (Construction Method Selection Model). Nevertheless, these tools do not adequately consider aspects of sustainability (Yunus and Yang, 2012). Sustainability involves such issues as the design and management of buildings, the performance of materials, operation and maintenance, long-term monitoring, and the dissemination of knowledge in related technical contexts. Moreover, most available systems and assessments, including diagnosis guidelines and tools, are used only once the design of the IBS building project is near completion (Nawi *et al.,* 2014b). Due to the uncertainty and complexity of IBS building maintenance and the diversity of project environments, maintenance management needs to be efficient at each stage of the lifecycle of the building.

Applications of CMMS to maintain a large number of buildings with high-quality methods can provide various reports pertaining to repair and maintenance issues that ensure better management of maintenance activities and achieve better quality of the transfer and evaluation of information among internal staff (Bucon and Tomczak, 2018). The CAFM system to improve the usability of buildings can help decision makers automate the organization of a large amount of intensive data for maintenance

management functions, and generally results in cost saving on a regular basis (Roka-Madarasz, Malyusz and Tuczai, 2016). At present, Building Information Modelling (BIM) is most often used as a new system in maintenance management processes for high-rise and complex IBS buildings that enable effective maintenance and maintenance-related data. BIM has the potential to help improve the quality of maintenance management by visualising a large amount of data on the building's lifecycle in addition to other software functions (e.g. CMMS and CAFM) (Motamedi *et al.,* 2014; Chien *et al.,* 2017). There are advantages for clients and contractors in using BIM as a digital building model in the maintenance phase, for which it contains detailed building specifications in a system that facilitates computer-based maintenance management controls (e.g. geometric information, functions, features, and parameters), thus allowing for the identification of errors immediately, and build collaboration among various professionals in design to generate improved coordination, and reducing the time needed and defects in buildings (Ghaffarian-Hoseini *et al.,* 2017). Many studies have suggested integrated BIM solutions for various projects throughout the lifecycle of buildings, including its maintenance management. According to Carbonari, Stravoravdis, and Gausden (2016), the conceptual design in the BIM system is ideal for high-rise IBS buildings to support consistent visualization and design, cost estimation, evaluation, monitoring, retrofit planning, lean maintenance, and enhancement of collaboration between maintenance teams. Kensek (2015) investigated the possibility of detecting potential defects using BIM technology in an effort to carry out effective operations and maintenance work, particularly in complex projects. Taghavi *et al.,* (2018) also examined the use of BIM and sensor technology in an integrated manner to identify the state of the building in the construction project and gather information related to defect diagnosis and prevention for IBS building maintenance.

This paper proposes a framework for the application of the BIM-based Computerised Maintenance Management System (CMMS) expert in managing maintenance for high-rise IBS buildings. Using the proposed prototype system, defect diagnosis and the decision-making process in construction are rendered easier, faster, and more cost effective in terms of maintenance assessment, defect diagnosis, and control of components of IBS building structures than conventional methods of construction. It also helps reduce the risk of defects in the design, such as the design calculation error, to provide high-quality components for the IBS building structure to ensure a safe and healthy environment.

METHODOLOGY

Case studies were undertaken on eight IBS buildings to identify problems in their maintenance management, prevalent approaches to addressing these problems, the implementation of ICT, and the use of emerging technologies and the maintenance management system (MMS) to obtain information on process for maintenance identification, assessment, planning, and execution. Eight maintenance clients/contractors were selected based on major problems in using the conventional method (paper-based reports/unsystematic databases) for comparison to investigate maintenance management practices in each IBS building. There were 51 contractors for IBS building maintenance according to a classification of the Precast Concrete (PC) system, the highest number among IBS building maintenance projects in Malaysia according to the CIDB. Most used the conventional method and inadequately employed modern ICT tools (Nawi *et al.,* 2014b). This indicates that the use of ICT is remains limited for PC system classification in IBS building

maintenance management in Malaysia. The recommended sample size for interviews to obtain satisfactory results is between six (Morse, 1994) and 25 (Polkinghorne, 1989; Cited in Creswell, 2007) subjects "who have all experienced the phenomenon" (Creswell, 2007, p. 61); hence, eight key professionals working in IBS building maintenance units were interviewed for this study.

The synthesis of good practices for maintenance operations in the BIM-based CMMS Expert was based on the findings of the interviews and case studies. A total of 73.5% of IBS building maintenance in Malaysia features the use of the conventional method (Ismail *et al.,* 2016). The synthesis of good practices also features a cross-case analysis grouped into five "embedded units of analysis:" maintenance management problems, approaches to address these problems, ICT implementation, use of emerging technologies, and the proposed maintenance management system. This paper is part of a larger research project, and only introduces and discusses the framework of the proposed system in the following sections.

Synthesis of Good Practices

Table 1 below represents solutions suggested based on the case studies to improve current practices in maintenance management by implementing three approaches to the PC building. The analysis of Cases A, B, C, D, F, G, and H suggests improving the transfer of knowledge of defect diagnosis by combining the current system with related software technologies, such as CMMS and CAD. The problem of knowledge transfer in defect diagnosis also affects other PC buildings, and its significance is clear. Maintenance contractors have inadequate knowledge to handle the problem of defects, and struggle to gather accurate information records for inspection and planning. Another suggestion by clients/contractors was to use the transfer of knowledge to improve the quality of maintenance of structures and facilities in PC buildings (Cases A, B, D, F, G, and H). All related cases faced problems with the quality of knowledge management, which are associated to the defect repetition for handling the defect of structures and facilities with IBS score usage about 70% on its structure development of PC building.

Table 1: Proposed solutions from case studies

No.	Suggested Solutions	Case A	Case B	Case C	Case D	Case E	Case F	Case G	Case H
1	Provide more transfer of knowledge in defect diagnosis	/	/	/	/		/	/	/
2	Improve the maintenance quality in maintenance execution	/	/		/		/	/	/
3	Implementation of emerging technology (BIM) (efficient control of building performance based design/ monitor the defect component operation in maintenance)	/	/	/	/	/	/	/	/

The analysis of Cases C, D, E, F, and G suggests efficient control of design based on building performance and monitoring the operation of defect diagnosis in maintenance through the implementation of an emerging technology (BIM) to PC building maintenance. Cases A, B, and H also point to the need to integrate the design/construction and database of maintenance to facilitate better decision support and coordination within and across multiple fields (e.g. civil, mechanical, and electrical) for the effective management of PC building maintenance. This suggested solution was ranked the most important solution in almost all case studies. The use of emerging technologies is also the poorest in terms of current practices. As the overall

results indicate in Table 1, it is necessary to analyse the use of emerging technologies further. Therefore, a system featuring emerging technologies, defect diagnosis, and the decision-making process should be developed to improve the building structure and facility performance by effectively transferring knowledge related to the maintenance defects in components of the structure.

LESSONS

1. PC building maintenance and the application of diagnostic techniques should be attended to. Because of the repetition of defects in components of the structure and limited understanding of PC buildings, the approach taken to maintenance is important. The application of modern ICT tools, such as BIM, can help avoid or alleviate defects in critical structure.
2. Appropriate ICT tools should be selected in areas of assessment (diagnosis and decision-making process concerning the design specifications used and construction implemented) for PC buildings. High-rise structures should be prioritised for these types of PC buildings.
3. The deficiencies in knowledge of PC buildings affect the competence of maintenance staff in Malaysia. Future work should seek to guarantee their competence in cases of defect repetition.

Requirements for Integrating Maintenance Management System

There were many problems related to the conventional method in the maintenance management of PC building, such as defect repetition (leaking, jointing, and cracking) and a lack of competent contractors. The conventional method also led to inaccurate design and construction information, late updates to the required information, and lack of coordination and integration. The high quality of IBS buildings and the long lifespan of the services require efficient management to maintain the building structure and facility at the PC building. Therefore, it is important to transform the conventional process into computer-based systems to improve maintenance management processes for complex projects, especially in the post-occupancy period of a building. In the case studies, the maintenance clients/contractors revealed a number of shortcomings in the conventional method. The knowledge of defects in the building was inadequate to help the maintenance management staff to handle the data and diagnose defects. The record of information was also inaccurate and could not be used to assess the conditions of components and make relevant decisions. The repetition of defects was frequent in PC buildings. Maintenance inspection and assessment had been unable to address defects in the buildings' structure in particular locations owing to a lack of knowledge transfer among members of maintenance management departments. Furthermore, incompetent contractor caused maintenance faults to increase.

In this study, a system is proposed to address the maintenance management problems in PC buildings, which are as follows:

a) defect repetition due to the failure to identify reasons for structure defects;
b) defect repetition (leaking, jointing, and cracking) due to design defects; and
c) incompetent contractors owing to a lack of knowledge of materials, methods, and design of structural repairs.

The processes consisted of: (1) Defect Report and Assessment; (2) Defect Diagnosis; (3) Defect Control, and (4) Report Protection, and are shown in Figure 1. Improvements to the maintenance management process in this system are as follows:

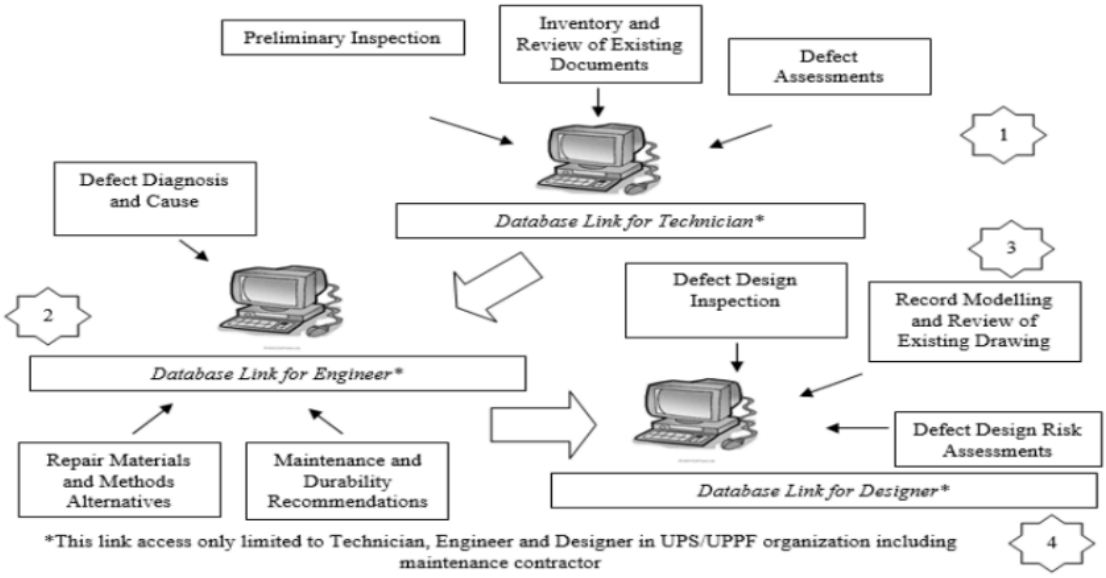


Figure 1: Configuration of improvements to maintenance management processes

1. Defect Report and Assessment: In report form, the user can enter data on the given structure and type of facility, and defect description, location, and visual inspection. The aspect of building can be classified as 'structures', 'finishes', 'mechanical', and 'electrical' in the system.
2. Defect Diagnosis: The system is considered a decision-making tool, and a comprehensive computerised expert system that provides recommendations on the components of PC structures. This defect diagnosis process is used to allow the user to select from among three knowledge bases—leaking, jointing, and cracking in concrete, including the selection of appropriate construction design or materials and recommended methods for repair. Engineers are expected to use this diagnostic to identify defects and determine their causes.
3. Defect Control: The BIM database is developed to provide technological transfer of knowledge from specialists to other practitioners, and vice versa, and provides a common forum for communication between designers and engineers. Therefore, it is a useful guide to everyone dealing with defects in components of PC structures. It is an excellent first-hand reference for a wide range of risks of defects in structural design and can facilitate accurate analysis using a design condition index coupled with an independent computerised expert system.
4. Report Protection: Access to all information in the maintenance management database is restricted because it includes personnel files, and documentation for the design, construction, and maintenance phases of the building.

Proposed Maintenance Management Processes

From the findings of the case studies, the process of maintenance management is maintenance identification (for defect report and assessment), defect and cause analysis (for defect diagnosis), and risk-level analysis (for defect control). These are the main stages in managing maintenance for PC buildings. The defect report and assessment are the initial process where a technician identifies defective components

in the building. The defect inspection is then undertaken to assess the defect on site, and this information is entered in the system. The database of the system is linked with the three software, namely, the CMMS, Expert System, and BIM model. Knowledge transfer can then be used through this system when knowledge concerning the history of defect in a given component is provided to the engineer in the same organisation from the defect report and assessment. The engineer is assigned to screen each defect component for diagnosis to analyse the cause and reason for the defect. The expert system can be used to examine symptoms of the defect in each component based on knowledge from the literature, codes of practice, manuals, textbooks, technical reports, journals and conference proceedings, civil work reports, and experienced PC specialists.

This process of diagnosis consists of three knowledge bases, each of which contains information on the various features of defects in PC structures (e.g. shape, pattern, density, and location). The knowledge needed for diagnosing defects in the PC building is formulated as production rules (IF … THEN) and procedures and are incorporated into the knowledge base. These are typical forms of code in conventional programming languages. The entry type procedure of the knowledge base uses syntax similar to the Visual Basic programming language within the body of the procedure. Knowledge of defect diagnosis in the Expert System is then transferred to the designer in the BIM model for investigating causes of the design defect and reasons for it, and even to classify the level of risk posed by it. Finally, knowledge of the design defect based on specifications of the materials and visual information of the BIM model is transferred back to the engineer for work planning and maintenance execution. The knowledge transfer in this system improves the defect diagnosis and decision-making processes for critical defects.

System Architecture

The system architecture focuses on collecting structural and facility-related defect information for defect assessment, diagnosis, and control as well as an analysis of the data for execution reference in PC building maintenance. Such devices as laptops enable staff to compare and adapt the data at any facility using the staff report recorded in the prototype system's user interface (MS Visual Basic.NET). The staff can thus capture knowledge of the structure and defects in the facility, update details, and record the relevant aspect of defect attribution in the electronic form of the prototype. This knowledge is stored in a computer database centrally (MS Access) linked to the technician, engineer, and designer at the maintenance organisation for further processing. Information on the defect is assessed using the maintenance condition index to consider the given condition of the structure and its components, analysed for maintenance defect diagnosis using the decision-making process, and assessed using the design condition index to reduce the risk of design defects at the site. The specific maintenance workflow is illustrated in Figure 3. The 'CMMS Expert using BIM' can be divided into three components, BIM, CMMS, and Expert System. Each component plays a different role in the prototype system. BIM technology enables the analysis of defects in components of the concrete structure by comparing them and can generate a 3D model in the BIM database, whereas the CMMS stores the defect report and assessment. The Expert System contains knowledge of defect diagnosis, and the selection of a durable replacement design and material or the proper rehabilitation method for the system.

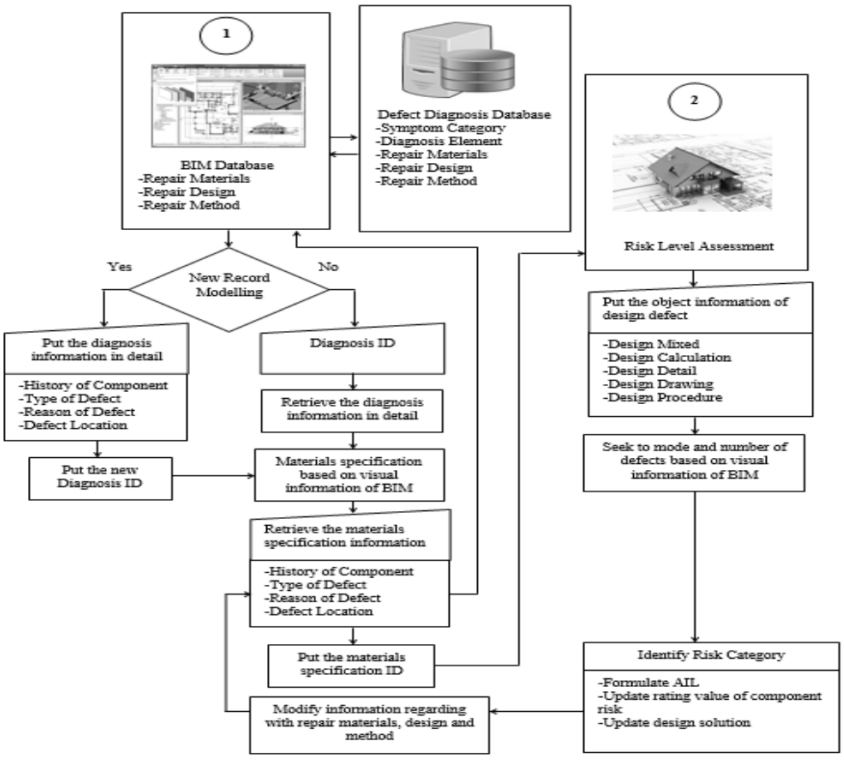


Figure 3: Defect maintenance process using CMMS, Expert System, and BIM

DISCUSSION

The prototype system was frequently tested by running it until critical problems had been fixed and the staff were confident in their ability to understand its functional requirements. The aim of testing the prototype system was to form several phases of the current value chain model (AS-IS) and construct a modified value chain model (TO-BE) with improvements to the prototype system (Yunus *et al.,* 2010). It provided the available structured system tools within an organisational context and a process modelling technique as the final refinement to install a system for application to maintenance management practices in IBS buildings.

CONCLUSIONS

Building a BIM-based CMMS Expert in an integrated manner is a vital task of IBS building maintenance. The framework proposed here helps engineers and researchers improve their knowledge of diagnoses of defects in components of IBS building to reduce risks of design defects throughout the building's lifetime. The use of technology to support maintenance processes and activities can have a positive impact on the delivery of service. Several systems have been developed to facilitate decision making support in IBS building maintenance. However, efficient practice requires a system that can handle decision making support in the context of diagnosis in an effective way. The proposed BIM-based CMMS Expert facilities can enhance decision making support in defect diagnosis.

REFERENCES

Bucon, R and Tomczak, M (2018) Decision-making model supporting the process of planning expenditures for residential building renovation, *Technological and Economic Development of Economy*, 24(**3**), 1200-1214.

Carbonari, G, Stravoravdis, S and Gausden, C (2016) Building information model for existing buildings for facilities management: RetroBIM framework, *International Journal of 3-D Information Modeling*, (IJ3DIM), 5(**1**), 1-15.

Chang, C and Tsai, M (2013) Knowledge-based navigation system for building health diagnosis, *Advanced Engineering Informatics*, 27(2013), 246-260.

Chien, S C, Chuang, T C, Yu, H S, Han, Y, Soong, B H and Tseng, K J (2017) Implementation of cloud BIM-based platform towards high-performance building services, *Procedia Environmental Sciences*, 38(2017), 436-444.

Chiu, C and Lin, Y (2014) Multi-objective decision-making supporting system of maintenance strategies for deteriorating reinforced concrete buildings, *Automation in Construction*, 39(2014), 15-31.

Cresswell, J W (2007) *Qualitative Inquiry and Research Design: Choosing among Five Approaches.* London: Sage Publications.

Ghaffarian-Hoseini, A, Zhang, T, Nwadigo, O, Naismith, N, Tookey, J and Raahemifar, K (2017) application of nD BIM integrated knowledge-based building management system (BIM-IKBMS) For inspecting post-construction energy efficiency, *Renewable and Sustainable Energy Reviews*, 72(2017), 935-949.

Ismail, Z (2014) System development toward effective maintenance management practices, *Built Environment Project and Asset Management*, 4(**4**), 406-422.

Ismail, Z, Mutalib, A A and Hamzah, N (2016) Case study to analyse problems and issues in IBS building maintenance, *International Journal of Applied Engineering Research*, 11(**1**), 226-232.

Kamar, K A M, Hamid, Z A, Zain, M Z M, Rahim, A H A, Ghani, M K, Azman, M N A, Majid, T A and Ahamad, M S S (2012) Drivers and barriers of industrialised building system (IBS) Roadmaps in Malaysia, *Malaysian Construction Research Journal*, 9(**1**), 1985-3807.

Kamsu-Foguem, B and Noyes, D (2013) Graph-based reasoning in collaborative knowledge management for industrial maintenance, *Computers in Industry*, 64(2013), 998-1013.

Kensek, K (2015) BIM guidelines inform facilities management databases: A case study over time, *Buildings*, 5(**3**), 899-916.

Mohamad, D, Ramli, M Z, Danuri, H N and Sapuan, W K (2016) Demand of the industrialized building system (IBS) Implementation in Malaysian government projects, *Journal of Scientific Research and Development*, 3(**4**), 77-82.

Motamedi, A, Hammad, A and Asen, Y (2014) Knowledge-assisted BIM-based visual analytics for failure root cause detection in facilities management, *Automation in Construction*, 43(2014), 73-83.

Morse, J (Eds.) (1994) *Handbook of Qualitative Research*. Thousand Oaks, California: SAGE Publications.

Nawi, M N M, Salleh, N A and Anuar, H S (2014a) A review study of maintenance and management issues in IBS commercial building, *International Journal of Computer Informatics and Technological Engineering*, 1(**1**), 42-46.

Nawi, M N M, Haron, A T, Hamid, Z A, Kamar, K A M and Baharuddin, Y (2014b) Improving integrated practice through **b**uilding Information Modelling-Integrated Project Delivery (BIM-IPD) for Malaysian Industrialised Building Systems (IBS) construction projects, *Malaysia Construction Research Journal (MCRJ)*, 15(**2**), 1-15.

Polkinghorne, D (Ed.) (1989) *Existential-Phenomenologifial Perspectives in Psychology*. New York: Plenum.

Roka-Madarasz, L, Malyusz, L and Tuczai, P (2016) Benchmarking facilities operation and maintenance management using CAFM database: Data analysis and new results, *Journal of Building Engineering*, 6(2016), 184-195.

Ruiz, P A P, Kamsu-Foguem, B and Noyes, D (2013) Knowledge reuse integrating the collaboration from experts in industrial maintenance management, *Knowledge-Based Systems*, 50(2013), 171-186.

Taghavi, M, Heredia, H, Iturralde, K, Halvorsen, H and Bock, T (2018) Development of a modular end effector for the installation of curtain walls with cable-robots, *Journal of Facade Design and Engineering*, 6(**2**), 1-8.

Yunus, M Z B M, Ramli, M Z B and Mesir, B B (2010) *Civil Engineering Information System 12th Edition*. Skudai: Universiti Teknologi Malaysia.

Yunus, R and Yang, J (2012) Critical sustainability factors in industrialised building systems, *Construction Innovation*, 12(**4**), 447-463.

Zakaria, S A S, Brewer, G and Gajendran, T (2012) Contextual factors in the decision making of industrialised building system technology, *International Journal of Civil, Architectural Science and Engineering*, 6(**7**), 34-42.

SCIENTOMETRIC ANALYSIS AND MAPPING OF DIGITAL TECHNOLOGIES USED IN CULTURAL HERITAGE FIELD

Lukman Mansuri[1], Chika Udeaja[2], Claudia Trillo[3], Gyau Kwasi[4], Dilip Patel[5], Kumar Jha[6], Chikomborero Busisiwe Makore[7] and Sakshi Gupta[8]

[2,3,4&7] *School of Science, Engineering and Environment, University of Salford, Maxwell Building, Salford M5 4WT, UK*

[1&5] *Civil Engineering Department, Sardar Vallabhbhai National Institute of Technology, Ichchhanath, Surat - 395007, India*

[6&8] *Department of Civil Engineering, Indian Institute of Technology Delhi, Hauz Khas, New Delhi, India*

BIM and other digital technologies are increasingly applied to buildings under construction with limited attention to existing and heritage buildings. Recent studies, through a critique of the literature, have sought to analyse the application of BIM in heritage. However, excepting the limited number of these studies, attention is often given to a specific digital technology or heritage aspect to the neglect of how other constituents of the entire digital technology regime and the recent developments therein could be applied in the heritage sector. This implies there is a knowledge gap regarding the overview of the application of digital technologies within the heritage sector. This study aims to systematically analyse the recent development of digital technologies such as Building Information Modelling (BIM) or Heritage Building Information Modelling (HBIM) in cultural heritage with the aim to provide insight into the overall potential for future research, current challenges and capabilities of digital technologies within the heritage sector. The chosen methodology for this study is scientometric analysis by using both quantitative and qualitative review processes. The findings from this study reveal that the main emerging digital technology researched in the field of cultural heritage is BIM or HBIM. There is evidence of multidisciplinary research within the body of knowledge and an increase in collaborative research between the areas of remote sensing, image science, computer science, architecture, archaeology and history. However, there is an unbalanced dominance of research partnership among authors and institutions in Europe. Research collaboration with global institutions is therefore encouraged as a necessity for advancing the applicability of digital technologies in the heritage sector. This study has implications for academics, research institutions, practitioners and policy makers, assisting these stakeholders to make vital contributions to advancing intellectual wealth to the research area of digital technology and heritage.

Keywords: BIM, HBIM, digital, cultural heritage, Scientometric Analysis

[12] c.e.udeaja@salford.ac.uk

Mansuri, L, Udeaja, C, Trillo, C, Kwasi, G, Patel, D, Jha, K, Makore, C B and Gupta, S (2019) Scientometric Analysis and Mapping of Digital Technologies Used in Cultural Heritage Field *In:* Gorse, C and Neilson, C J (Eds) *Proceedings of the 35th Annual ARCOM Conference,* 2-4 September 2019, Leeds, UK, Association of Researchers in Construction Management, 255-264.

INTRODUCTION

The extensive benefits of digital technologies for the Architectural, Engineering, Construction and Operation (AECO) industry are increasingly recognised in academic and professional practice (Logothetis *et al.,* 2015, Manferdini and Galassi 2013, Pocobelli *et al.,* 2018, Xu *et al.,* 2014). A digital technology that has gained significant attention in this industry is Building Information Modelling (BIM) and more recently is its application to the heritage sector, which is the focus of this paper. Diverse building projects involving historic buildings and sites such as, conservation and refurbishment, adaptive salvage, defensive maintenance, heritage management, interpretation, documentation and research have created opportunities for the use of BIM in innovative ways. The combination of BIM with Heritage, also known as HBIM (Heritage Building Information Modelling) can efficiently support design and build decisions resulting in the production of sustainable and inclusive heritage assets. Despite this, BIM is mostly applied to buildings under construction and BIM and other digital technologies for heritage assets are relatively new fields of academic research. Studies have provided an appropriate analysis of BIM in heritage through critical literature reviews by focusing on Computer Aided Design (CAD) and BIM (Logothetis *et al.,* 2015), the use of BIM to capture and store data (Pocobelli *et al.,* 2018), digital tools and techniques for heritage documentation (Cheng *et al.,* 2015, Vandenbulcke *et al.,* 2015). However, excepting the limited number of these studies, attention is often given to a specific digital technology or heritage aspect to the neglect of how other constituents of the entire digital technology regime and the recent developments therein could be applied in the heritage sector. As a result, there is a paucity of research that provides an overview of the application of digital technologies, beyond BIM within the heritage sector.

It is within this context, that this study aims to systematically analyse the recent developments and provide insights into potential future research, current challenges and capabilities of digital technologies within the heritage sector. This is achieved through a scientometric analysis which visualises global trends and patterns of research through mapping top influential authors, journals, articles, countries, institutions and keywords in the field of digital technologies, HBIM and Heritage. The research findings contribute to the global body of heritage and digital technologies knowledge by providing a detailed understanding of the current landscape. The findings call for further interrogation into the application of digital technologies in the heritage sector by identifying where best to focus future research efforts. Furthermore, this study contributes to practice by serving as a valuable and updated reference for supporting policy makers' and practitioners' planning and funding efforts in heritage and area of digital technologies.

This study draws from the initial studies undertaken within a larger research project, " IT INDIAN HERITAGE PLATFORM: Enhancing cultural resilience in India by applying digital technologies to the Indian tangible and intangible heritage". The overall aim of the project is to enhance the cultural resilience of the Indian tangible and intangible cultural heritage, challenged by rapid urbanisation, by exploiting the potential of digital technologies applied to the heritage (Gupta and Jha, 2018; Mansuri and Patel, 2018). Therefore, this paper is divided into four broad sections. Section two discusses the methodology used for developing this study including the data collection and selection of the scientometric tool and data acquisition. This is followed by a discussion of the findings from the scientometric analysis and mapping in section three and section four concludes the discussion with recommendations.

METHODOLOGY

Scientometric analysis

Drawing on the aim of the study as discussed above, the chosen methodology is scientometric analysis. A significant range of research areas in the field of digital technologies and heritage exist and therefore it is challenging to represent and summarise the entire knowledge domains through a manual conventional literature review process. Furthermore, conventional reviews are inclined to be subjective and present biased opinions (Yalcinkaya and Singh 2015). This method limits the study exploration to "what" questions, rather than "how" and "why". Consequently, it is suitable for providing a possibility to comprehensively and quantitatively analyse literature resources in a generic way that can yield valuable information and provide a broad view on the topic and its current status and relevance.

Scientometric analysis is defined as the "quantitative study of science, communication in science, and science policy" (Hess 1997). It measures the impact of authors, articles, journals, institutes and understanding of citations, mapping scientific fields and visualisation of indicators for policy making and management (Leydesdorff and Milojević 2012). This method is ideal for this study because it identifies and analyses the evolution of the research over time. It is a quantitative approach that visualises and maps the development of research (Konur 2012) by relying on largescale bibliographical data to assess the development of the research domain through different qualitative indexes (Mingers and Leidesdorff, 2015).

Data collection

Data collected from the Web of Science (WoS) core collection database was used for this study. WoS is the world's leading citation database, covering over 12,000 high-impact journals. This database possesses a wide range of publication coverage including indexing among science citation index (SCI), social science citation index (SSCI), conference proceeding citation index and emerging source citation index. A limitation to this method is the dependence on the database extracted for the study and therefore any limitations of the coverage of publications. An additional limitation is that the analysis only covered literature indexed in WoS core collection with publications in the English language. A study comparing numerous databases for scientometric analysis by Mingers and Leidesdorff, (2015) has shown that the WoS database has accurate and reliable information and can be considered sufficient to showcase the patterns and trends of digital technologies in the heritage sector.

Selection of scientometric tool and data acquisition

For the purposes of this study, the Java application "CiteSpace (5.3.R4 version (64-bit)" is used. According to a comparative review of scientometric software conducted by Cobo *et al.,* (2011), several scientometric tools such as Bibexcel, CiteSpace, CoPalRed, IN-SPIRE, Leydesdorff's Software, Network Workbench Tool, Sci2Tool, VantagePoint, and VOSViewer, have been developed within the last few years resulting from emerging interest in identifying the fundamental foundations and trends of a research area(s). Cobo *et al.,* (2011: 1400) conclude that although the comparative review does not incorporate all the science mapping software tool, a thorough scientometric analysis within any field could be carried out using any of the tools. The study described CiteSpace as a comprehensive tool that is suitable for identifying the hidden connections between the different scientific contributions with an advanced network visualisation feature. It also possesses all the features and

characteristics required to compute the WoS database which has further motivated the choice to its use in this study.

Searching attempts were conducted from the detailed search section by syntax using the following phrase: "TS = (digital technology* OR building information model* OR BIM AND (heritage OR historic* OR as-built OR hbim))". The search results were further refined manually resulting in the removal of irrelevant and misleading titles from the database. By manually reading titles and abstracts, all the related and relevant articles were sorted and later exported for analysis in CiteSpace. The final search results contain a total of 194 articles dated up to March 2019. Out of these records, 67 are journal articles, 125 are proceedings papers and 3 are review papers. Analysis of these documents is explored in the following sections.

FINDINGS

Scientometric analysis and mapping

The findings from the scientometric visualisation and analysis are presented in this section. Emerging technologies, research areas, influencing authors, countries and journals are visualised by co-author, co-word and co-citation analysis which are described in the following sub-sections.

Digital technologies (frequent keywords)
The keyword network provides an opportunity for the revelation of scientific knowledge which reflects the relationship, pattern and covered topics. Therefore, this study categorised the context and concept of research articles with the associated keywords. The keywords are the representing words and concise description which serve as the reference in finding and retrieving the article concept and content. As a result of this co-word analysis, the highly frequent (n) keywords in the network reveal the emerging technologies in the field of cultural heritage, which are as follows: "BIM" (n = 67), "HBIM" (n = 34), "cultural heritage" (n = 31), "point cloud" (n = 22), "laser scanning" (n = 14), "architecture" (n = 11), "documentation" (n = 10), "conservation" (n = 10), "architectural heritage" (n = 10), "photogrammetry" (n - 10), "laser" (n = 9).

The digital technologies through the network of keywords (as indicated in Figure 1) reveal three key findings within the global heritage literature.

- The overall research area can be divided into two main categories: (1) digital tools and (2) digital technologies. The top 10 keywords reflect digital tools such as laser scanning, point cloud and photogrammetry while the main digital technologies are BIM and HBIM.
- Figure 1 shows that several research areas (nodes) are in isolation with the core network. This suggests that areas such as object recognition, algorithm, free/open source software and digital documentation remain unexplored or under researched. The availability and accessibility of areas such as open source software can determine the development of digital technologies for cultural heritage. Other areas such as photogrammetric restitution, geometric modelling and digital documentation are also isolated and not of noticeable importance in current literature but have significant potential for future development in cultural heritage.
- Future research areas can be identified from this analysis. Several potential research areas such as heritage management, digital heritage documentation and information system are forming a substantial body of literature. However,

there is a visible gap from the main research areas such as BIM and HBIM. This reveals opportunities for future research to fill that gap. Additionally, there is huge potential of development in the field of Virtual Reality, Artificial Learning, machine learning, object detection and algorithms, which can advance automation in the field of cultural heritage documentation and conservation.

Figure 1: Digital technologies (network of keywords)

Emerging research areas (WoS Subject categories)

This study used the subject classified bibliographic records by WoS based on the scope of the corresponding article and journal to determine the main subject categories and the emerging technologies in cultural heritage. One article can be assigned more than one subject category.

The analysis revealed 10 top subject categories in the corpus of digital technologies for cultural heritage: (1) Remote sensing, (2) Image science, (3) Photographic technology, (4) Computer science, (5) Physical geography, (6) Architecture, (7) Archaeology, (8) Construction and building technology, (9) Geosciences, (10) History. As illustrated in Figure 2, the research in the field of digital technologies for cultural heritage is very diverse and from different disciplines. This advancement of multidisciplinary research illustrates an increase in collaborative research between the remote sensing, image science, computer science, architecture, archaeology and history.

Figure 2: Research areas (Network of subject categories)

The network of subject categories shows that areas such as remote sensing, image science, photographic technology and computer science are making significant contributions towards the development of digital technologies in the field of cultural heritage. This may include increasingly popular technologies such as Internet of Things, nanotechnologies and robotics. Whilst areas such arts and humanities remain unusually isolated area in the network despite the potential to elevate the heritage research field. The circuit of geology, archaeology and geoscience also has huge potential to merge with the main research body to contribute to cultural heritage.

Most contributing authors, institutions and countries

As part of this study, the scientometric analysis conducted, revealed the most contributing authors, their institute and country of research (Table 1) to the field of digital technologies and heritage. This is meaningful for developing a picture of the collaboration network of the authors and institutions which have high investment and interest in heritage and digital technologies. Additionally, this information is useful in identifying research groups and assisting research partnerships and policy-making. According to the analysis, the most influential authors are based in Europe with core active authors publishing from Italian institutes, particularly the Polytechnic University of Milan. This suggests that the top institutes (Table 1) are successful in providing the infrastructure facilities as well as the expertise to support the undertaking of research in the multidisciplinary area of digital technologies for cultural heritage.

To add to the results from Table 1 is the illustration of the collaboration network of different countries leading in digital technologies research for cultural heritage in Figure 3. In this Figure, the size of the font size and the influence circle discloses the contribution of research in the field. The results from the analysis of network support the author analysis by revealing the top five most contributing countries having more than 10 articles (n) published as: (1) Italy (n = 66), (2) China (n = 24), Spain (n = 17), Germany (n = 13) and Canada (n = 12).

Italy stands out as the most contributing country along with significant contributions from USA, Spain, Germany, England and Canada. The linkage or research collaboration are not as strong as desired because, all the countries are connected with

links but there is no cross inter connection which demonstrates a need for all the countries to redefine their collaboration efforts and policies.

Table 1: Top 10 most contributing authors

Sr. No.	Author Name	Institute	Country	No. of Articles
1	Maurice Murphy	Dublin Institute of Technology	Ireland	7
2	Fabrizio Banfi	Polytechnic University of Milan	Italy	5
3	Luigi Barazzetti	Polytechnic University of Milan	Italy	5
4	Daniela Oreni	Polytechnic University of Milan	Italy	5
5	A. Adami	Polytechnic University of Milan	Italy	4
6	Jan Boehm	University College London	United Kingdom	4
7	F. Chiabrando	Polytechnic University of Turin	Italy	4
8	Stefano Cursi	Sapienza University of Rome	Italy	4
9	Stephen Fai	Azrieli School of Architecture and Urbanism, Canada	Canada	4
10	F. Fassi	Polytechnic University of Milan	Italy	4

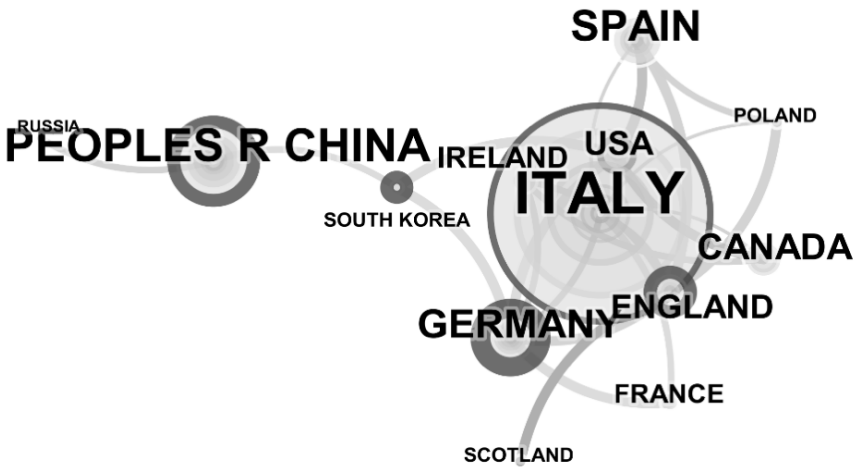


Figure 3: Collaboration network of countries

China appears disconnected from the main body research community, suggesting that the institutions in these countries could benefit from promoting collaboration and knowledge exchange in the digital technologies and heritage knowledge domain. Other countries like Russia, Scotland, South Korea and Poland have weak collaboration networking with the main community. This needs to be taken into consideration by redefining their research collaboration policies. The Euro-dominance illustrated from this analysis also reveals a paucity in collaborative contribution from Global South countries like India, Brazil and Mexico and regions of Africa. Although these locations have a significant number of UNESCO World Heritage Sites, the underrepresentation in the network suggests a lack of resource, expertise and awareness of digital applications within the heritage sector.

DISCUSSION AND RECOMMENDATIONS

Results from the scientometric analysis discussed in the previous sections demonstrate that the current global body of digital technologies and heritage knowledge still has

gaps and limitations, which become evident when the large corpus of literature is analysed. It is clear that the main emerging digital technology researched in the field of cultural heritage is Building Information Modelling (BIM) or Heritage Building Information Modelling (HBIM). To date, special attention has been directed to BIM and HBIM while being biased toward other themes such as the use of laser scanning, point cloud and photogrammetry and digital technologies explored as a means to facilitate the modelling and documentation of monuments, sites and artefacts results into BIM. This is illustrated in studies such as Quattrini *et al.,* who developed a 3D model for complex architectural shapes by using the Terrestrial Laser Scanning (TLS) (Quattrini *et al.,* 2015). In the same vein, Xu *et al.,* developed a digital point cloud model using the camera-equipped unmanned aerial vehicle and the TLS (Xu *et al.,* 2014). Laser scanning is confirmed in studies as an accurate tool for recording geometric information but, it is very costly affair, while photogrammetry can become the substitute for modelling and documentation, which is possibly a cost-effective solution. More economical combinations have been explored by Manferdini and Galassi who review the use of traditional topographic techniques with range-based (laser scanning) and photogrammetry. Their study concluded that the combination of traditional technologies and photogrammetry are more economical but require high accuracy and skills (Manferdini and Galassi 2013).

Some studies have focussed particularly on the application of digital technologies for the documentation of heritage assets. A framework for the documentation of cultural heritage sites is proposed by Baik *et al.,* based on Jeddah HBIM by integrating 3D BIM and 3D Geographic Information System (GIS) (Baik *et al.,* 2015). Using laser scanning and photogrammetry, Cheng *et al.,* further explored the potential of digital tools for heritage documentation (Cheng *et al.,* 2015). The comparison of laser scanning and the photo modelling for as-built BIM is also reviewed by Vandenbulcke *et al.,* (2015) and concluded that both techniques result in high resolution documentation (Vandenbulcke *et al.,* 2015). However, there is still a need for further research and development in the area of photogrammetry in order to gain higher accuracy. The literature suggests that BIM is a relevant and valuable digital asset for the documentation of the cultural heritage. On the contrary, there are other tools and technologies available for as-built geometric modelling, but these tools are to some extent not capable of documenting the artistic and monumental parts of the cultural heritage. Artificial Intelligence tools such as object recognition and algorithms can assist in developing the applicability of these tools to build accurate models fast and cost effective. Other technologies such as Computer Aided Design (Logothetis *et al.,* 2017), Virtual Reality (Rua and Alvito 2011) and Augmented Reality (Osello *et al.,* 2018) also present the opportunity for further exploration in the cultural heritage sector and HBIM.

The findings of this study reveal evidence of multidisciplinary research within the body of knowledge (Figure 1 and 2) and an increase in collaborative research between the areas of remote sensing, image science, computer science, architecture, archaeology and history. However, notwithstanding the benefits of research collaboration, there is an unbalanced dominance of research partnership among authors and institutions in Europe and particularly, Italy (Table 1 and Figure 3). This study therefore recommends that research collaboration with global institutions should be encouraged as a necessity for advancing the applicability of digital technologies in the heritage sector. Focus should be given to the formulation of policies to encourage collaborative research by funding agencies to underrepresented regions such as Global

South countries in South America, Asia and Africa. Additionally, this study recommends the attention of digital technologies such as Artificial Intelligence, CAD, Virtual Reality and Augmented Reality by authors in this field as well as further exploration into the development of open source software for research and development purposes to further advance the applicability and research of these digital technologies.

CONCLUSIONS

This paper represents the results of a scientometric analysis of digital technologies and BIM in cultural heritage and provides a detailed overall picture of the body of knowledge. Key research concerns along with opportunities and recommendations for further research have been identified. The methodology of the study, scientometric analysis was carried out using 194 articles indexed by the WoS. Moreover, the study is based on a qualitative analysis of literature and minimum subjective judgments therefore the findings are justified and reliable. Methodological limitations discussed in section two of this study create opportunities for future research. This overall review explored by this study confirms that digital technologies are valuable to both researchers and practitioners to develop better products and solutions for the conservation, preservation and management of cultural heritage. Further updates of the overall status of this research area can be updated at key intervals in the future to assess the updated existing body of knowledge in the field of digital technologies for cultural heritage.

ACKNOWLEDGMENT

This work is a part of an ongoing project 'IT INDIAN HERITAGE PLATFORM: Enhancing cultural resilience in India by applying digital technologies to the Indian tangible and intangible heritage' funded by Arts and Humanities Research Council (AHRC), UK [project reference: AH/R014183/1] and the Indian Council of Historical Research (ICHR), New Delhi, India.

REFERENCES

Baik, A Yaagoubi, R and Boehm, J (2015) Integration of Jeddah historical BIM and 3D GIS for documentation and restoration of historical monument, *In:* Y N Yen, K H Weng and H M Cheng (Eds.) *25th International CIPA Symposium 2015*, 31 August - 04 September Taipei, Taiwan, 29-34.

Pocobelli, D P, Boehm, J, Bryan, P, Still, J and Grau-Bové, J (2018) BIM for heritage science: A review, *Heritage Science*, 6(**1**), 30.

Cheng, H-M, Yang, W-B and Yen Y-N (2015) BIM applied in historical building documentation and refurbishing, *In:* Y N Yen, K H Weng and H M Cheng (Eds.) *25th International CIPA Symposium 2015*, 31 August - 04 September Taipei, Taiwan, 85-90.

Cobo, M, Lopez-Herrera, A, Herrera-Viedma, E, and Herrera, F (2011) Science mapping software tools: Review, analysis and cooperative study among tools. *Journal of the American Society for Information Science and Technolog*y, 62, 1382-1402.

Gupta, S, Jha, K N (2018) Building information modelling for smart regeneration of cultural heritage: Transforming cultural heritage into smart heritage for development, *In*: *National Conference on Smart and Sustainable Cities (Ssc18)*, 12-13 December, Sardar Vallabhbhai National Institute of Technology Surat (SVNIT Surat), India.

.

Hess, D J (1997) *Science Studies: An Advanced Introduction*. New York: New York Univeristy Press.

Konur, O (2012) The evaluation of the global research on the education: A scientometric approach, *Procedia-Social and Behavioral Sciences*, 47, 1363-1367.

Leydesdorff, L and Milojević, S, (2012) Scientometrics. *In*: M Lynch (Ed) (2015) *International Encyclopedia of Social and Behavioral Sciences,* Section 8.5: Science and Technology Studies, Subsection 85030.

Logothetis, S, Karachaliou, E, Stylianidis, E (2017) From OSS CAD to BIM for cultural heritage digital representation, *In:* D Aguilera, A Georgopoulos and T Kersten, F Remondino and E Stathopoulou (Ed.) *3D Virtual Reconstruction and Visualization of Complex Architectures*, 1-3 March, Nafplio, Greece, 439-445.

Manferdini, A M, Galassi, M (2013) Assessments for 3D reconstructions of cultural heritage using digital technologies, *In:* J Boehm, F Remondino, T Kersten, T Fuse and D Gonzalez Aguilera (Eds.) *3D-ARCH 2013 - 3D Virtual Reconstruction and Visualization of Complex Architectures*, 25-26 February, Trento, Italy, 167-174.

Mansuri, L E, Patel, D A (2018) Heritage Information Modeling: A conceptual framework for enhancing cultural resilience of Indian tangible and intangible heritage, *Mid Term Session and Seminar on Conservation and Restoration of Heritage, Indian Building Congress*, 23-24 June, Udaipur, India, 2349-7475.

Mingers, J, and Leydesdorff, L (2015) A review of theory and practice in scientometrics. *ArXiv, abs/1501.05462*.

Osello, A, Lucibello, G, Morgagni, F (2018) HBIM and virtual tools: A new chance to preserve architectural heritage, *Buildings*, 8(12).

R Quattrini, E.S Malinverni, P Clini, R Nespeca, E Orlietti, (2015) From TLS to HBIM high quality semantically-aware 3D modelling of complex architecture, *In:* D Gonzalez Aguilera, F Remondino, J Boehm, T Kersten and T Fuse (Eds.) *3D-ARCH 2015 - 3D Virtual Reconstruction and Visualization of Complex Architectures*, 25-27 February, Avila, Spain, 367-374,

Rua, H and Alvito, P (2011) Living the past: 3D models, virtual reality and game engines as tools for supporting archaeology and the reconstruction of cultural heritage - The case-study of the Roman villa of Casal de Freiria, *Journal of Archaeological Science*, 3296-3308.

A Vandenbulcke, A De Wulf, C Stal, R Goossens and G Deruyter (2015) Comparison of terrestrial laser scanning and photo modelling for the documentation of cultural heritage, *In*: *15th International Multidisciplinary Scientific Geoconference (SGEM 2015*), Sofia, Bulgaria, 1227-1234.

Xu, Z, Wu, L, Shen, Y, Li, F, Wang, Q and Wang, R (2014) Tridimensional reconstruction applied to cultural heritage with the use of camera-equipped UAV and terrestrial laser scanner, *Remote Sensing*, 6, 10413-10434.

Yalcinkaya, M and Singh, V (2015) Patterns and trends in building information modeling (BIM) Research: A latent semantic analysis, *Automation in Construction*, 59, 68-80.

TO FORMULATE A CONCEPTUAL MODEL FOR INNOVATION: REFRAMING THEORETICAL CONSTRUCTS OF BIM ADOPTION WITHIN SME ORGANISATIONS

Usman Makarfi[1] and Chika Udeaja

School of Built Environment, University of Salford, Maxwell Building, Salford M5 4WT, UK

The Construction industry is facing a paradigm shift in the adoption of new innovative ways of designing and delivering of projects. This innovative process includes building information modelling (BIM) which have shown significant impact on efficiency and effectiveness during a project development process within the construction industry. However, the shift to its acceptance, adoption and implementation in the emerging markets has brought distortion in the organisational culture, behaviour, and business processes of small medium enterprises (SMEs). This is often associated to the lack of clear orientation of the impact of BIM adoption to the firms. Although several theories have explained different concept relating to acceptance of innovative technologies within an organisation, however, it is crucial to understand this concept through the lens of BIM. Thus, this paper identifies the different theories concerning BIM acceptance within organisations and highlights the relationship between different factors that influence BIM acceptance within organisations. This was achieved by identifying the key factors that influence the acceptance of innovation and the process of adopting an innovation within organisations. The study involved a two-step analysis; systematic literature review and theoretical formulation. The systematic literature review was used to identify various theories and models that explains the acceptance process and behaviour of individuals during adoption of new innovations within SMEs organisations. The theoretical formulation was achieved by synthesizing the key influencing factors and indicators identified from the systematic literature review which were categorised into four groups namely; organisation, human, technology and relationship. The output was consolidated to form the conceptual model that would be the basis of further research and will help in understanding the relationship between factors that influence BIM acceptance process within SMEs organisation in the construction industry.

Keywords: BIM, conceptual model, innovation adoption, SME, theoretical construct

INTRODUCTION

Although the construction industry possesses a unique status in the development of a nation's economy, a diagnosis of the industry has shown lack of productivity and inefficiency in construction project delivery due to poor communication between construction stakeholders and the industry fragmented nature (Farmer, 2016). Studies have been carried out in response to the above accusations ranges from new contractual/procurement arrangements like partnering, concurrent engineering, integrated project delivery to innovations in ways to design and deliver construction

[1] u.u.makarfi@edu.salford.ac.uk

Makarfi, U and Udeaja, C (2019) To Formulate a Conceptual Model for Innovation: Reframing Theoretical Constructs of BIM Adoption Within SME Organisations *In:* Gorse, C and Neilson, C J (Eds) *Proceedings of the 35th Annual ARCOM Conference,* 2-4 September 2019, Leeds, UK, Association of Researchers in Construction Management, 265-272.

processes such as three-dimensional computer aided design and modelling (Underwood and Isikdag, 2011). However, building information modelling (BIM) is among such innovative process that promises to bring about continuous improvement and desired change within the construction industry (Matthews *et al.,* 2018).

Building information modelling has various definition. According to buildingSMART International, (2016), it is defined as "the digital representation of the physical and functional characteristics of a facility". Therefore, this aids in obtaining reliable information from a shared knowledge resource about a facility which can serve as a basis for decision making during the project lifecycle (Arayici *et al.,* 2011). BIM technologies benefits as claimed by its advocates includes improved data exchange and communication, improved collaboration and coordination of documents used in construction, improved design visualization and quantification, clash detection and cost reduction among others (Eastman, Teicholtz, Sacks, and Liston, 2012; Liu, van Nederveen, and Hertogh, 2017). Furthermore, countries that have adopted BIM at various level of their construction projects and documented substantial evidence of improvement in project delivery (Liu *et al.,* 2017; Wong, 2018).

The nature of BIM will not allow firms to do the same things in a new way and therefore it is difficult to come up with a single model of BIM adoption for the AEC industry. According to Aranda-Mena *et al.,* (2008) 'In order for a business case to be reliable, it must be developed to achieve specific objectives or outcomes taking into consideration the particular needs and characteristics of the company. The clearer the objectives are defined, and the specific circumstances of the company analysed, the better the business case will be.' It is especially true with the small and medium enterprises considering their nature and culture. Thus, the aim of this paper is to develop a conceptual model of BIM acceptance that will have the power to demonstrate acceptance and usage behaviour of BIM within SME's through; (a) identifying the key research trends of BIM adoption within SME, (b) identifying the theoretical models related to innovation adoption with a focus on BIM and, (c) identifying the key factors that influence BIM adoption within organization. A Thorough understanding of the model will help practitioners to analyse the reasons for resistance toward the BIM and will also help to take efficient measures to improve BIM usage and acceptance within SME.

Innovation Diffusion Theories

Crucial to examining the prospects of BIM adoption in a given context, particularly amongst the small and medium size firms, it is important to establish the level of how similar technologies are adopted in that context and identify the specific factors that affect it. According to Rogers, (2010), the level of innovation adoption can be determined or gauged by several factors. Perhaps most important among them are subjective perceptions derived from personal experiences. These perceptions and how they are shared across networks are shown to drive the innovation diffusion process. BIM is a complex tool that requires fundamental changes in existing methods. These qualities are likely to produce subjective perceptions and personal experiences that seriously impact the diffusion process. Rogers continues to define five stages involved in the adoption process, knowledge, persuasion, decision, implementation, and confirmation as seen in the Figure 4. These stages provide a basis to formulate a theoretical framework for investigating adoption process of BIM in the small and medium-sized firms. Theories of Diffusion of Innovation by Rogers, (2010) is, therefore, crucial to this research, which is determining emerging models in the wake

of ICT adoption in the Nigerian context. The unit of analysis for this study will be the small and medium size architectural firm as an organisation.

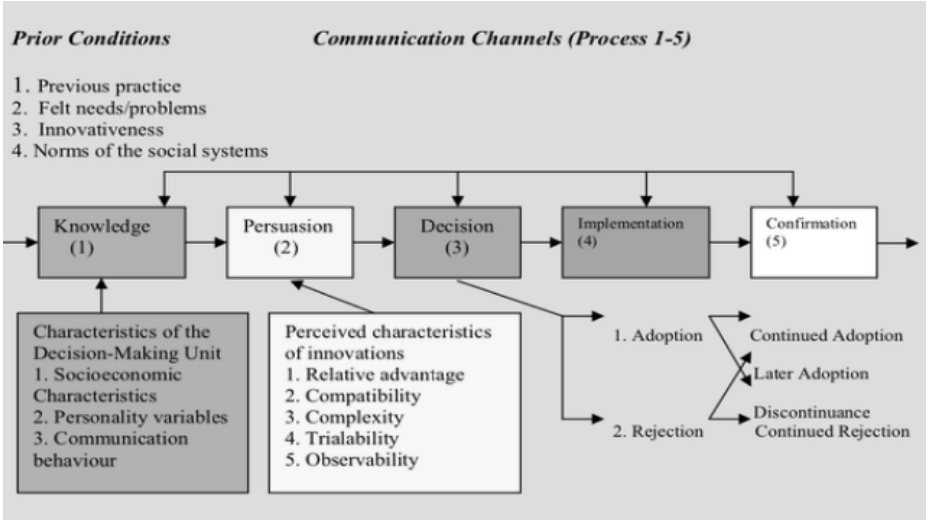


Figure 1: A model of innovation diffusion theory (Rogers, 1995).

Technology Acceptance Model

One of the key measures of identifying level of BIM adoption is achieving the intended level of usage of the technology. Kim *et al.,* (2017) claimed that users' positive attitude and belief in technology are related to user tendencies in accepting technology and therefore, technology usage is a reflection of acceptance by users. Similarly, while BIM usage has many benefits for information management in the AEC, the usage of BIM as new technology causes increased BIM user's resistance. The factors causing BIM user resistance are rather not necessarily technological but environmental factors and organization-related factors of the users. That is, if organizations are not ready for these factors, it is difficult for a BIM user to obtain the expected positive effects from BIM usage.

Technology acceptance model (TAM) introduced by Davis *et al.,* (1989) is an adaptation of the theory of reasoned action (TRA) and the theory of planned behaviour (TPB) specifically tailored for modelling this user behaviour in acceptance of technology. The goal of TAM is to provide an explanation of the determinants of technology acceptance that is capable of explaining user behaviour across a broad range of end-user computing technologies and user populations, while at the same time being both parsimonious and theoretically justified. In this model, perceived usefulness and perceived ease of use are of primary relevance for Information Systems (IS) acceptance behaviour as seen in Figure 2.

METHODS

There are different methods to carry out systematic literature review (SLR) which are all explicit, rigorous and comprehensive (Albliwi *et al.,* 2015). According Pinho *et al.,* (2018), the most quoted method of SLR in the area of Social Sciences are, (1) Planning the review, (2) Carrying out the review and (3) Disseminating the results obtained. This research adopted similar method.

The databases that were used to carry out the search are namely; Scopus, Web of Science, EBSCO host and Emerald Insight. The search expression as detailed below is existing on the topic or title, keywords and abstract. The area of the search was

restricted to research papers, articles, reviews, conference papers and conference reviews that are written in English language within the last decade.

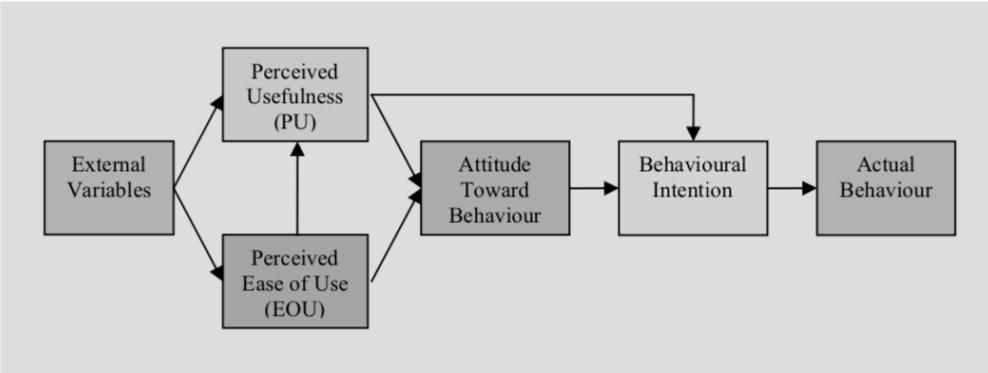


Figure 2: Technology acceptance model (Davis, Bagozzi, and Warshaw, 1989)

After this process the Scopus database produced a total of 93 articles, the Web of Science produced 6, the EBSCO host produced 7 and the Emerald Insight produced 5, making a total of 111 articles. Subsequently, using Mendeley Desktop referencing tool version (1.19.3), 3 duplicate articles were removed leaving a total of 108. The selected articles were further presented using VOS viewer which is a computer program developed for constructing and viewing bibliometrics mapping using graphical representation.

Table 1 shows the number of documents retrieved from each step of the search process. Step I, Step II and Step III are different search strings as shown below while Step IV involved additional criteria to ensure that only articles relevant to the study are selected. The search strings are as follows:

1. Step I: ("building information modelling" AND bim)
2. Step II: ("building information modelling" AND bim) AND (adoption* OR implementation*)
3. Step III: ("building information modelling" AND bim) AND (adoption* OR implementation*) AND ("SME")
4. Step IV: Excluding the irrelevant document types and restricted the number of years to (2010 -2019).

Table 1: Number of articles retrieved from various databases.

	Step I	Step II	Step III	Step IV
Scopus	4,174	2,296	108	93
Web of Science	1,125	528	6	6
EBSCO host	8,290	720	8	7
Emerald Insight	329	281	12	5

RESULTS

Analysis of BIM Adoption Research Trends Based on Bibliographic Coupling

Studying the bibliographic network among 108 publications in our dataset, three distinct clusters can be identified. Figure 3 illustrates a relative coherent bibliographic network on BIM adoption within SME publication published between 2010 and 2019. It shows three major distinct clusters namely; construction industry, information modelling and building. These are the most frequent keywords used.

Figure 4 shows the number of articles related to BIM adoption published between 2010 - 2019. There is a steady increase in the number of articles published which shows a growing interest in BIM research. The highest of which is 2018 which has almost double the previous year.

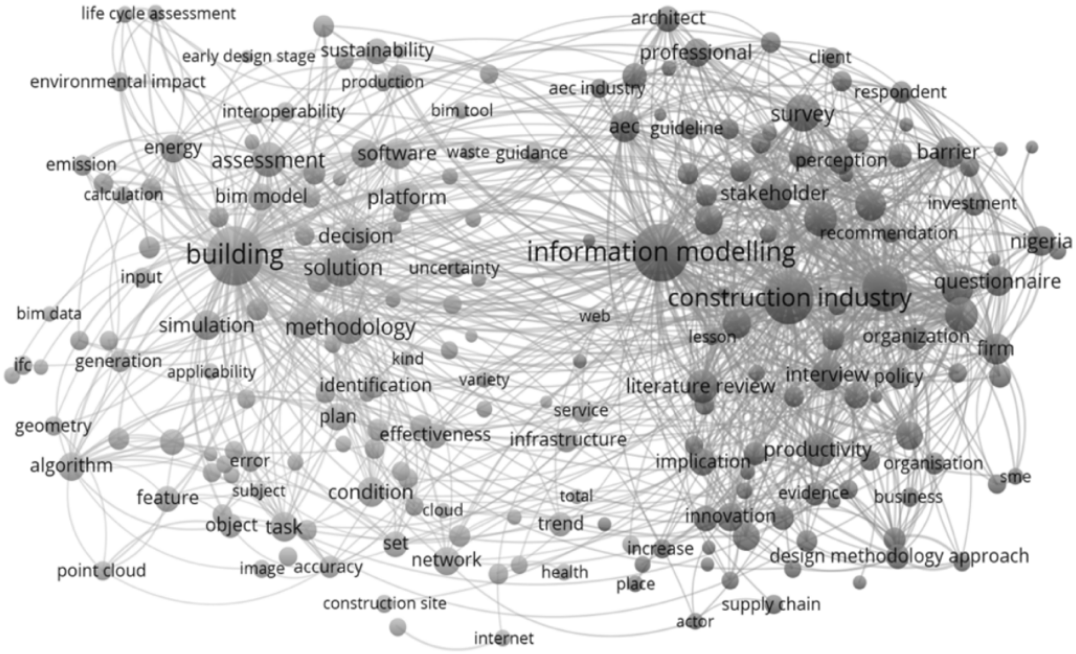


Figure 3: Network of BIM adoption within SME publications published between 2010-2019

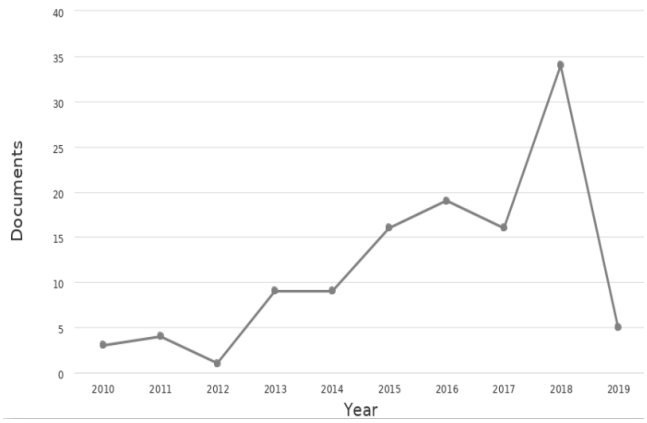


Figure 4: Number of articles published between 2010 and 2019 related to BIM adoption within SME.

Conceptual Model

Figure 5 shows a proposed conceptual model which contains two major components. The first component is adapted from the technology acceptance model which include perceived ease of use, perceives usefulness, attitude towards usage and intention to use. This are identified as factors that influence the acceptance of technology in this case, BIM. The second factors identified from literature are categorised into four. Studies have identified the compatibility of technology, the competency of the firm, the behaviour control and the quality of technology as external factors that influence BIM acceptance (Lee *et al.,* 2015).

TAM proposes that external variables indirectly affect attitude toward use, which ultimately leads to actual system use by influencing perceived usefulness and perceived ease of use. However, several studies later proposed extended version of Davis's TAM by adding external variables in it with the aim of exploring the effects of external factors on users' attitude, behavioural intention and actual use of technology. Several factors have been examined so far. For example, perceived self-efficacy, facilitating conditions, and systems quality (Fathema *et al.,* 2014). However, Revised Roger's theory of innovation diffusion (Rogers, 2010) also mentioned five (5) factors as external variables of acceptance and perception; Relative Advantage, Compatibility, Complexity, Trialability, Observability. This factors provided the principal theoretical perspective on technology acceptance which has been applied at both individual and organisational levels of analysis while its primary intention is to provide an account of the manner in which any technological innovation moves from the stage of the invention to widespread use (or not) (Dillon and Morris, 1996). Integrating both the theories of the Innovation diffusion by Rogers and that of technology acceptance model by Davis is essential for achieving the aim of this study.

Table 2: Constructs of the BIM conceptual model

Construct	Description
Organisation	These are the ability of the firm in terms of effectiveness, infrastructure, willingness to motivate and innovative processes to support new technology.
Relationship	These has to do with the impact of internal pressure form colleagues, the influences arising from external pressure i.e. other professionals and the image and reputation to be maintained to the environment.
Human	The human factor has to do with the motivation and capability of the top management and employees to accept and use the technology. The consensus is the extent to which they jointly take a decision as to accept or reject the use of technology.
Technology	These are the extent to which the technology can benefit and be suitable to the organization. It also has to do with the perceived ease of the technology towards producing the desired output and the degree of compatible with the current work flow and processes.
Intention to use	Intention to accept BIM are willingness to encourage the use of BIM among group constituents, willingness to recommend the use of BIM to other organizations in cooperative relationships, and willingness to develop BIM application technology

Table 2 shows the construct of BIM conceptual model and the description of each variable. There are four main categories of factors namely; the organisation, human, relationship and technology. These factors are the first layer of the conceptual framework and have indicators that influence them. Taking the "organisation" as an example, the indicators include; process, infrastructure and competence. The details of each factor are discussed in the table 2. The second layer of the conceptual model is the intention to use and attitude towards usage. This is adapted from the figure 2 (the technology acceptance model). This have an influence on the core of the conceptual model (the actual usage).

CONCLUSIONS

The aim of this paper is to develop a conceptual model of BIM acceptance that will have the potential to demonstrate acceptance and usage behaviour of BIM within SME's. A systematic and comprehensive review of literature (including 108 articles) was presented to identifying the key research trends of BIM adoption within SME and the theoretical models related to innovation adoption with a focus on BIM. From the selected articles, the key factors that influence BIM adoption were identified and

categorised into groups. These key factors would be the presumed variables that might influence BIM adoption. A conceptual model was then developed by consolidating the results and findings. However, Further research towards improving BIM usage and acceptance within SME would be conducted using the conceptual model as a base.

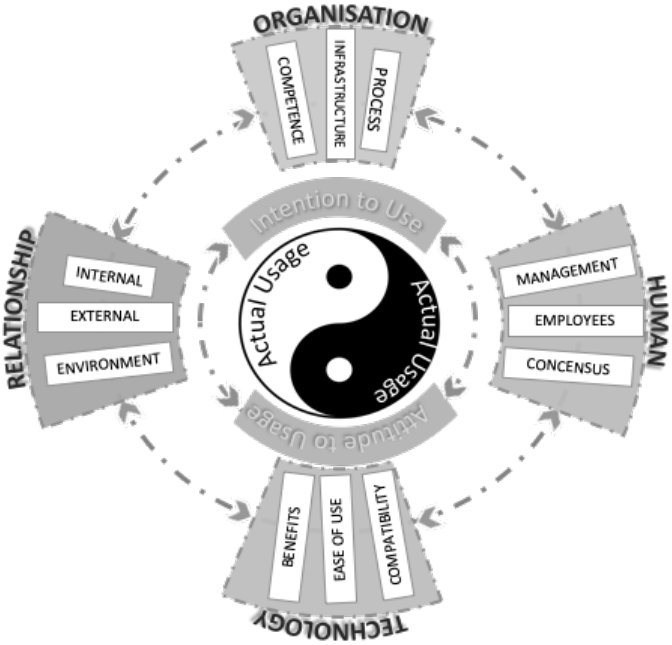


Figure 5: Conceptual model adapted from different models

REFERENCES

Albliwi, S A, Antony, J and Lim, S A Halim (2015) A systematic review of Lean Six Sigma for the manufacturing industry, *Business Process Management Journal*, 21(**3**), 665-691.

Aranda-Mena, G, Crawford, J, Chevez, A and Froese, T (2008) Building Information Modelling demystified: Does it make business sense to adopt BIM? *International Journal of Managing Projects in Business*, 2, 419-434.

Arayici, Y, Coates, P, Koskela, L, Kagioglou, M, Usher, C and O'Reilly, K (2011) BIM adoption and implementation for architectural practices, *Structural Survey*, 29(**1**), 7-25.

buildingSMART International (2016) buildingSMART Technical Vision. Available from http://buildingsmart.org/standards/technical-vision/

Davis, F D, Bagozzi, R P and Warshaw, P R (1989) User acceptance of computer technology: A comparison of two theoretical models, *Management Science*, 35(**8**), 982-1003.

Dillon, A and Morris, M G (1996) User acceptance of information technology: Theories and models, *Annual Review of Information Science and Technology*, 31, 3-32.

Eastman, C, Teicholtz, P, Sacks, R and Liston, K (2012) *BIM Handbook: A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers and Contractors*. Hoboken, NJ: J Wiley & Sons.

Farmer, M (2016) Modernise or Die, Available from http://www.cast-consultancy.com/news-casts/farmer-review-uk-construction-labour-model-3/ [Accessed 2nd August 2018].

Fathema, N, Ross, M and Witte, M M (2014) Student acceptance of university web portals, *International Journal of Web Portals*, 6(**2**), 42-58.

Kim, H-Y, Lee, J Y, Mun, J M and Johnson, K K P (2017) Consumer adoption of smart in-store technology: Assessing the predictive value of attitude versus beliefs in the

technology acceptance model, *International Journal of Fashion Design, Technology and Education*, 10(**1**), 26-36.

Lee, S, Yu, J and Jeong, D (2015) BIM acceptance model in construction organizations, *Journal of Management in Engineering*, 31(**3**), 04014048.

Liu, Y, van Nederveen, S and Hertogh, M (2017) Understanding effects of BIM on collaborative design and construction: An empirical study in China, *International Journal of Project Management*, 35(**4**), 686-698.

Matthews, J, Love, P E D, Mewburn, J, Stobaus, C and Ramanayaka, C (2018) Building information modelling in construction: Insights from collaboration and change management perspectives, *Production Planning and Control*, 29(**3**), 202-216.

Pinho, C, Franco, M and Mendes, L (2018) Web portals as tools to support information management in higher education institutions: A systematic literature review, *International Journal of Information Management*, 41, 80-92.

Rogers, E M (2010) *Diffusion of Innovations*. New York: Simon and Schuster.

Underwood, J and Isikdag, U (2011) Emerging technologies for BIM 2.0, *Construction Innovation*, 11(**3**), 252-258.

Wong, S S Y (2018) A review on the execution method for BIM projects in Hong Kong, *Proceedings of the Institution of Civil Engineers: Management, Procurement and Law*, 171(**3**), 100-110.

EFFECTIVENESS OF ADOPTING BIM ON QUANTITY SURVEYING PROFESSION DURING THE PROJECT LIFE CYCLE

Soleen Alhasan[1], Omar Amoudi[2], Michael Tong[3] and Bimal Kumar[4]

[1&2] *Department of Built and Natural Environment, National University of Science and Technology, Muscat, Sultanate of Oman*

[3] *Department of Construction and Surveying, Glasgow Caledonian University, Glasgow, Cowcaddens Road, G4 0BA, UK*

[4] *Department of Architecture and Built Environment, Northumbria University, Newcastle-upon-Tyne, NE1 8ST, UK*

Despite the significant role of the construction industry in nation's wealth and development, the construction industry usually suffers from poor performance in terms of time and cost overruns. This is due to its characteristics in terms of complexity, fragmented nature, a large number of involved parties and a wide range of professions. Quantity surveyors (QSs) profession is one of the key professions with many essential tasks over project life cycle. BIM has been claimed by various professions in the construction industry to enhance the project performance and tackle many problems within it. This research aims to evaluate the effectiveness of adopting BIM on QS profession and its performance in a construction project. The literature was intensively reviewed to determine the main responsibilities of QS over project life cycle when it works the main project parties (client and consultant). In this part of research, the implication of the use of BIM has been specifically dealt with the work in pre-construction stage. A set of criteria were extracted and identified based on the main responsibilities of QS profession by conducting structured interviews with clients and consultants. Many scenarios were produced, after modelling a multi-storey building project utilizing Revit Architecture Software, to reflect the effectiveness of using BIM with various tasks of QSs. The model facilitates generation of different scenarios based on outcomes. The initial results revealed that adopting BIM improves the accuracy and reliability of QSs outputs at early stage of project and enhances the documentation of project performance over project life cycle. Also, the results demonstrate that project parties get benefits, from BIM adoption by their QSs, in terms of more reliable budgeting, less errors in quantities measurement, better documentation considering the limitation of adopting BIM, lack of BIM standard and the compatibility between the BIM software.

Keywords: surveying, project life cycle, 5D BIM, industry foundation classes

INTRODUCTION

The construction industry, nowadays, is developing at a rapid pace and contributing to growth of nation's economy (Seed, 2015) further to its contribution to the economy of the country's gross national input, Kumar (2015). It is considered as a major productive sector besides its strong linkages with other industries (Durdyev& Ismail,

[1] soleenalhasan@nu.edu.om

Alhasan, S, Amoudi, O, Tong, M and Kumar, B (2019) Effectiveness of Adopting BIM on Quantity Surveying Profession During the Project Life Cycle *In:* Gorse, C and Neilson, C J (Eds) *Proceedings of the 35th Annual ARCOM Conference,* 2-4 September 2019, Leeds, UK, Association of Researchers in Construction Management, 273-282.

2012). In construction, client's needs are prioritised on the one hand and the benefits of other stakeholders on the other (Chini and Valdez, 2003). Despite of its large investment growth and its contribution to the economics, the construction industry is still struggling from underperformance in term of quality and productivity (Love, *et al.,* 2013). Construction projects are very complex in nature, due to the multi interchangeable activities; result in lack of coordination and ineffective communication (Gamil and Abdul Rahman, 2017). Two common challenges faced by the construction industry related to documentation including the quality of data generated and utilised during the project; and the ways of communicating and sharing the relevant data between the stakeholders (Crotty, 2012). These problems as indicated by Purnus and Bodea (2015) may affect the timely completion of the project at the predetermined budget, agreed level of quality and the end profitability. Further, Akmal *et al.,* (2018) specified that, unreliable cost of the construction projects, which is developed during the construction stages, could lead to unhealthy construction environments, create more complication towards the project closing, and influence the predetermined objectives of the project outcomes and targets, hence the overall project success.

Cost overrun, unpredictable completion and low productivity are considered as most frequently problems faced by the construction industry (Proverbs *et al.,* 2000). Accuracy in the quantity take-off process is one of the key functions in the construction industry which in turn affects project cost and the overall performance (Monteiro and Martin, 2013). Due to the complexity of the construction project, the industry may face financial challenges in term of poor productivity, profitability and inconsistent performance (Armstrong, 2017). In order to overcome and handle those problems, it is essential to maintain the value of the projects, by employing an innovative approach. Quantity surveyors play an important role in providing cost and contract advice on the built environment as pointed out by Cruywagen and Lille (2017) in addition to their crucial responsibilities towards the project parties over the project life cycle. Hence, acquisition and effective adoption of IT skills by the QS at an adequate level of knowledge, is required for more accuracy and reliability of construction cost. To do so, QSs must work with the latest technology such as BIM to improve the quality of the services provide by the QSs. The main objective of this paper is to provide a clear insight on the roles and responsibilities of the QSs and investigate the potential effectiveness of adoption BIM tools on the level of accuracy of quantity measurement.

Attributes of the Quantity Surveyors

Quantity survey is a major part of the construction scenario and determines to a great extent the changes in the economic growth, Purnus and Bodea (2015). QS has been defined by the renowned Seeley (1997) as a person who, on behalf of the employer, is professionally trained, qualified and experienced in dealing with building costs, construction management and construction communication issues. Since the QS is highly involved in many tasks and activities within construction projects, there is a need to assess the skills of the quantity surveyors, to understand their current approach to identify the opportunities and to address the market changes (Jennings and Betts, 1996). QSs have to monitor and provide a clear status about the financial situation of the project during the project life cycle with a high level of efficiency and consistency, (Cartlidge, 2018).

Success Criteria of Construction Project

The project success highly depends on the decisions and roles of quantity surveyors in achievements of the predetermined goals which influence the project efficiency in terms of time, cost and quality. Critical project success criteria as highlighted by Atkinson (1999) are closely linked to project effectiveness and productivity measurement. Such criteria are linked to the number of factors; time, cost and quality factors interrelated with each other. The iron triangle of time, cost and quality are the fundamental parameters for measuring project success throughout the life cycle of the project, as stated by Junior, Silva and Pacifico (2017) and agreed by Cunningham, (2013).

Building Information Modelling (BIM)

BIM is a modelling technology and associated set of processes to produce, communicate and analyse building model (Eastman *et al.,* 2012). BIM standards as declared by Crotty (2012) substantially improve the quality of the building drawings to provide a complete picture of the project and facilitate data interchange to be communicated more effectively amongst the project team members.

BIM and Quantity Surveyors

Several studies investigated the BIM adoption by QSs with main focus on quantity measurement, cost estimation, scheduling and planning (Kulasekara *et al.,* 2016). Hence, possession of IT skills by QSs is part of their basic responsibilities provided at the early stage of the construction project (Manzoor& Gunavel, 2017). BIM technology is becoming increasingly a new trend in the construction industry due to its rapid strides in improving the project productivity, efficiency and worldwide construction development. Distinctive attributes of BIM support in automating the construction process by establishing a flow of communication with the project team at all the project phases. Emergence of BIM in the QSs domain has remarkably changes the QS future, despite the challenges and barriers identified through various research studies (Kulasekara *et al.,* 2016). Estimation of the BIM models assists the quantity surveyors, to take an appropriate decision at the early stage to optimize the best outcomes to the stakeholders and all directly benefit from the project (Eastman, *et al.,* 2011). Forgues *et al.,* (2012), revealed that utilizing BIM technology in the area of the cost estimation; takes the project to the best value by applying the most effective quantity take off tools to decrease risk factors of inaccuracy, underestimate or overestimate, as well as shortening time required to completing estimation task with high level of accuracy.

Also, estimating of total cost of the construction project at the early stage of the design process, support the effective delivery process of high-quality project within the proposed budget and scheduled time line and avoid the inaccuracy resulting from the traditional practices. From this point of view, BIM adoption is promising to provide a unique source for accurate cost estimating for the entire lifecycle of the project. Although BIM adoption can bring many benefits to QS and other project professionals, but this is not free of challenges. The challenges of adopting BIM, comprise in the way of how the BIM model responding during the process of quantity take off and throughout the construction process. The scope is to complete the project as per the predetermined schedule and agreed budget Cunningham (2013) and to streamline the delivery of high-quality project (Eastman, *et al.,* 2011). Supportively, adopting BIM tools effectively by quantity surveyors improve the quality of the project (Kulasekara *et al.,* 2016). Quantity take off is one of the fundamental and most automated tasks could be completed with help of BIM tools by the quantity

surveyors form 2D drawings Gee (2010) and Monteiro and Martins (2013). BIM and its allied digital technologies and tools provide enormous opportunities for project cost management professionals to dramatically improve the quality, speed, accuracy, value and sophistication of their cost management services and therein ensure their future as key players in the BIM world (Smith, 2016). QSs are still behind to understand the full potential of BIM in the construction field. It is the time by the construction firms to embrace BIM technology and competing with other industries obtain the full benefits of such a technology. The greatest issues related to the quality/comprehensiveness of the BIM models, are comprising of not providing full access to the designers to the models and software/standards compatibility issues. Acquiring the benefit of adopting BIM technology, is associated with accuracy in estimation, resulting on the cost benefits. It is also linked to the developed model. If the developed models do not visibly reflect the project requirements, this will impact the construction cost as well as the project cost Love, *et al.,* (2013), considering the reliable construction cost as the critical success factor for successful implementing of BIM in the construction industry (Afaria *et al.,* 2018). To sum up, it is believed that BIM empowers project participant to play their roles in improve the project quality on time and predetermined budget. Project quality and productivity could be improved by enhancing the construction players' skills in running the project activities effectively and efficiently (Latiffi *et al.,* 2016). Variety of QTO software helps the quantity surveyors to eliminate the errors during the conventional process of quantity take off, hence, multi BIM based cost estimation programs have been developed (Plebankiewicza, Zimaa, and Skibniewski, 2015). Contrariwise, multi tools of estimation software/ BIM estimation packages lead to deviation in data produced. That is due to the lack of BIM standard, i.e., IFC which necessitates more attention to be paid to overcome the problems associated with BIM standards as raised through the current research.

Industry Foundation Class - IFC

Industry Foundation Class (IFC) has been established by International Alliance of Interoperability (IAI) in 1994. It is some continuous outcomes to the mission of the building SMART as mentioned in IFC (Laakso and Kiviniemi, 2012). The main objective of IFC is to enabling interoperability in the AEC/FM Industry. IFC is a neutral standard format for open BIM developed in different versions and not controlled by a singular vendor or group of vendors (Hernández *et al.,* 2018). It is described as an interoperability language and it is freely available on the web. The most widely common IFC is IFC 2x3 and the latest version released in 2013 is IFC4 which is yet to be incorporated with most of BIM software (Abanda *et al.,* 2017). The current research highlighted on the main issues raised associated with IFC while exporting the digital models between two common estimation digital tools of BIM.

Roles and Responsibilities of Quantity Surveyors During the Project Life Cycle

As the construction industry grows, more and more skilled roles become available, particularly in positions such as quantity surveyors. The responsibilities of QS vary over project life cycle and depending on the party to whom the QSs works for. Usually, quantity surveyors are responsible for the cost related issues of any construction project-from initial estimates to final material acquisition. Quantity surveyors as defined by RICS (2015) work as the cost managers in all sectors of the construction industry worldwide, since they are involved in all the construction phases from inception to completion and understand all the aspects of construction during building life cycle. They must have the ability to manage cost effectively, equating

quality and value with individual client needs. During capital expenditure phase, QSs are requested to be involved in the activities of studying the project feasibility, construction and execution, extension, refurbishment, maintenance and demolition of a facility. In the pre-construction, construction and post-construction phases of the whole building project, client, consultant and contractor QSs are involved, having essential skills for communication and troubleshooting, in the event of conflicts between the project parties. Monteiro and Martins (2013) indicated that QSs have IT skills for greater accuracy, provided at an early stage for the construction project to be feasible to fulfil the value system of the client.

RESEARCH METHODOLOGY

The methodology of the current research has been designed in two stages to achieve the main objectives. Stage 1 is designed for data collection through literature review and semi structured interview. Whereas Stage 2 is designed to extract quantities of the building elements through BIM software, Autodesk Revit and Naviswork.

Stage 1: Based on the literature review and following the roles and responsibilities of QS, four semi-structured interviews were carried out with consultants QSs and client to identify a set of criteria, to evaluate the QS effectiveness and rank their importance from the point of clients' and consultants' perspectives as shown in Figure 1. However, the criteria were classified into three main stages of the project life cycle, i.e., preconstruction, during construction and post construction and the QSs' responsibilities towards the clients, consultants and contractors have been identified as well. But, due to the limitation of the paper size, roles and responsibilities of the QSs towards the clients and consultants during the preconstruction stage were identified.

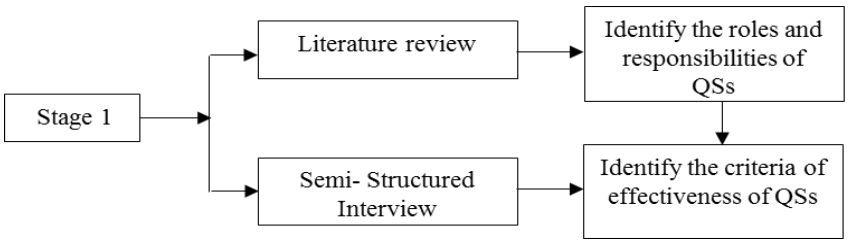


Figure 1 Research Methodology-Stage 1

Stage 2: A BIM model was built by using Autodesk Revit. The building model is a multi-use building consists of, two basement floors for parking and utilities, and six above ground floors for retail, offices, and residential flats. The building model comprises of four different engineering disciplines, Architectural, Structural, Electrical, and Mechanical. For the purpose of the current research, the quantities of structural elements of blinding foundation were extracted using Autodesk Revit and Naviswork. The process of extraction the quantities started by utilizing Autodesk Revit, meanwhile, the model was exported to Naviswork through IFC standard format. IFC standard was selected to study the compatibility between the BIM software and addressing the issues result in exporting the models between BIM software. Accordingly, the results from two packages were compared to evaluate the compatibility and were reflected to match the criteria of the QS effectiveness. The complete process is demonstrated in Figure 2.

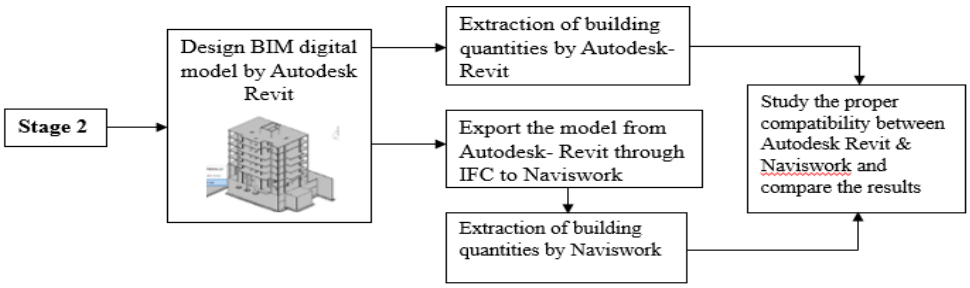


Figure 2 Research Methodology-Stage 2

DATA ANALYSIS AND RESULTS DISCUSSION

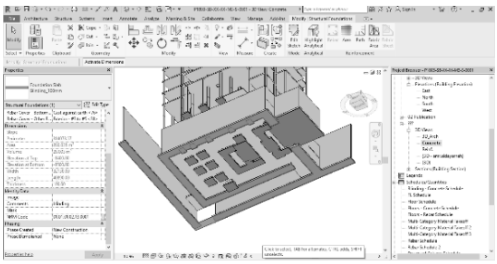
Stage1: Based upon the research methodology, stage 1, the essential criteria were identified as mentioned in the Table 1. Out of all the criteria identified, three major criteria comprising of; accuracy of quantities estimation, speed of quantities generation and cost analysis, planning and adherence to the timeline were the governing ones. The remaining criteria follow the major heads and can be seen Table 1 which summarises the main roles and responsibilities of QS during the preconstruction stage when working for various main parties and the final column show the criteria identified that can help in assessing the QS roles.

Table 1: Summary of the roles and responsibilities of QSs during preconstruction

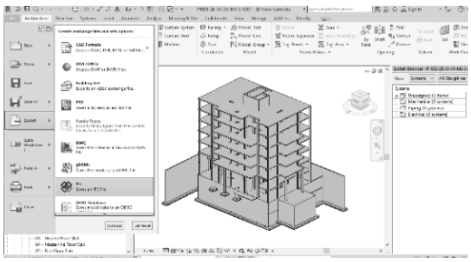
QSs duties / preconstruction stage	Project life cycle Pre-Construction Stage	Criteria ranked based on its importance
Clients	➢ Forecasting the overall project's cost at the initial stage. ➢ Act as a client's financial consultant during project progress. ➢ Ascertain the project feasibility and economic viability. ➢ Provide the client with valuable recommendation to maximize the benefits. ➢ Provide advice during the pre-construction on strategic planning, cost management and cost implications.	✓ Accuracy in estimation ✓ Certainty of Cost Prediction ✓ Cost analysis. ✓ Planning and adherence to the timeline. ✓ Quality of financial data ✓ Contractual administration ✓ Stakeholders satisfactions ✓ Stakeholders benefits ✓ Overall project performance ✓ Degree of improvement
Consultants	➢ Monitor the design team to ensure the design remains within the approved budget. ➢ Manage the financial aspects during the construction process. ➢ QSs, and the design team to figure out an appropriate solution within budget to provide the client with the best value for money. ➢ Produce an accurate priced bill of quantity. ➢ Preparation of tender and contract documents.	

Stage2: Based on the results obtained from stage2, the model was prepared considering the client's requirement and the consultant's specification. Keeping in mind the limitation in the size of paper the quantity analysis of blinding work in preconstruction stage was considered. The input data was fed in Revit and extracted to export in Naviswork through IFC. This is done in order for the QS to check the accuracy of the quantity to be extracted by any software and simultaneously to check its accuracy. It was found that there was a major incompatibility which can be owed to lack standard format which is IFC format as presented in Figure 2a. Phase1 shows the structural BIM model in which the quantity of blinding foundation as calculated in Revit is 28 m^3. Then, the model was exported to Naviswork through IFC and the quantity was found to be 58 m^3. It indicates that the quantity doubled in Naviswork reflecting huge incompatibility and non-feasibility of IFC standards. The foundation was re-modelled by changing the way the input data is fed as shown in Figure 2b.

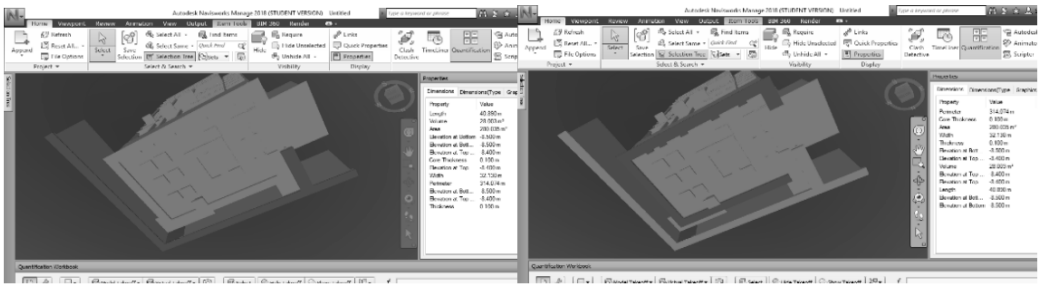
Phase 1- Building the Structural BIM Model and estimating the quantities



Step 1: Estimating the quantities of Blinding foundation = 28m³



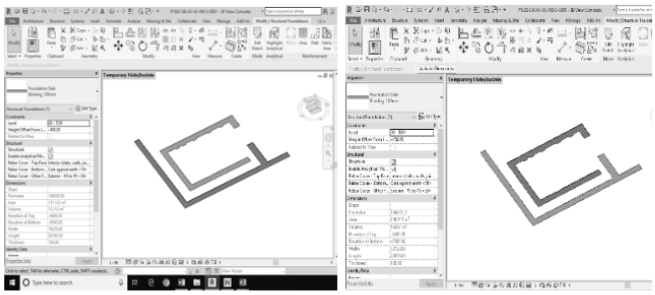
Step 2: Exporting the Model through IFC to Naviswork



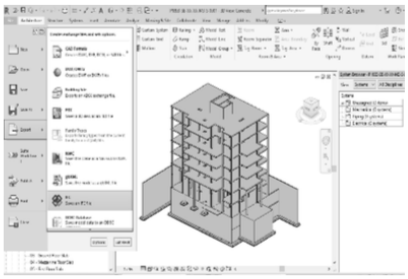
Step 3: Open the Model in Naviswork Estimating the quantities of Blinding foundation in Naviswork = 28x2= 56.0 m³

Figure 2a: Modelling, remodelling and estimating quantities of Blinding Foundation

Phase 2- Re-Building the Structural BIM Model and estimating the quantities§



Step 1: Estimating the quantities of Blinding foundation = 13.112 +14.891= 28.00m³



Step 2: Exporting the Model through IFC to Naviswork

Step 3: Open the Model in Naviswork Estimating the quantities of Blinding foundation = 14.89+13.112= 28.00 m³

Figure 2b: Modelling, remodelling and estimating quantities of Blinding Foundation

The quantity of blinding when calculated as individual entities showed to be the same as calculated in Revit in Stage 1. After transferring the model to Naviswork from

Revit through IFC, it was found the quantity remained the same, thereby, indicating that the way the input data is fed significantly reflects its accuracy.

This can be addressed in by creating two scenarios:

Scenario 1: - Rebuild the model where an anomaly to test the consistency between data results from both packages. It was found that both the software had a different way in reading the model. This was corrected by re-orienting the way input data was fed as shown in Figure 2b. After rebuilding the model as mentioned in scenario 1, it was found that the discrepancy in the result was overcome and the quantity of concrete in blinding was consistent with that calculated quantities using the software. This shows that the data should be input in a way which the BIM commercial software can in synchrony with other software.

Scenario 2- It is to change the design specifications from perspective of the project parties which need further research, keep in mind the necessity in understanding the nature and complexity of the design specifications and the methods of incorporating those specifications in the BIM digital model.

CONCLUSIONS

The accuracy in estimation of quantities based on the criteria considered was effective adopting BIM. However inaccurate quantity estimation would affect the cost analysis and therefore overall project cost would also be affected. Also, it needs time to remodel after identifying the deficits and exporting to Naviswork again. It also consumes a lot of time in the process of rebuilding the model. Hence, it is required to relook how effectively BIM can be adopted by QS for the success of a project and to meet the satisfaction of the client. Most of the construction companies are reluctant to adopt BIM, despite its varied benefits, just for the reason that there is lack of BIM standards. This limitation of IFC can be addressed by suggesting ways to develop and improve IFC standard so that it become an easy and effective reckoner in widely used quantity estimation tools. Because of these limitations in adapting to BIM, the QS normally prefer to stick to the conventional methods of quantities estimation and refraining from adopting other tools of BIM.

REFERENCES

Abanda, F H, Kamsu-Foguem, B and Tah, J H M (2017) BIM - New rules of measurement ontology for construction cost estimation, *Engineering Science and Technology,* 20(**2**), 443-459.

Afaria, M F A, Lib, H, Pärnc, E A and Edwards, D J (2018) Critical success factors for implementing building information modelling (BIM): A longitudinal review, *Automation in Construction*, 91, 100-110.

Akmal, N, Ismail, A, Idris, N H, Ramli, H, Sahamir, S R and Rooshdi, R R R M (2018) Sustainable BIM-based cost estimating for quantity surveyors, *Chemical Engineering Transactions*, 63, 235-240.

Armstrong, G (2017) *Global Construction Survey, Make It, or Break It*. Available from https://home.kpmg/xx/en/home/insights/2017/10/global-construction-survey-make-it-or-break-it.html [Accessed 3/04/2019].

Atkinson, R (1999) Project Management: Cost, Time and Quality, two best guesses and a phenomenon, it's time to accept other success criteria, *International Journal of Project Management*, 17(**6**), 337-342.

Cartlidge, D (2018) *New Aspects of Quantity Surveying Practice Fourth Edition*. Abingdon: Routledge.

Chini, A R and Valdez, H E (2003) ISO 9000 and the U.S construction industry, *Journal of Management in Engineering*, 19(**2**), 69-77.

Crotty, R (2012) *The Impact of Building Information Modeling, Transforming Construction*, London: Spon Press.

Cruywagen, H and Llale, J (2017) The role of quantity surveyors in public-private partnerships in South Africa, *South African Journal of Economic and Management Sciences*, 1015-8812.

Cunningham, T (2013) *Factors Affecting the Cost of Building Work - An Overview*, Dublin Institute of Technology. Available from https://arrow.dit.ie/cgi/viewcontent.cgi?article=1028&context=beschreoth [Accessed 28/07/2019].

Cunningham, T (2014) An Introduction to Taking off Building Quantities: An Irish Approach. Dublin Institute of Technology. Available from https://arrow.dit.ie/cgi/viewcontent.cgi?article=1031&context=beschreoth [Accessed 28/07/2019].

Durdyev, S and Ismail, S (2012) Role of the construction industry in economic development of Turkmenistan, *Energy Education Science and Technology Part A: Energy Science and Research*, 29(**2**), 883-890.

Eastman, C, Teicholz, P, Sacks, R Liston, K (2011) *BIM Handbook: A Guide to Building Information Modelling for Owners, Managers, Designers, Engineers and Contractors*. Hoboken, NJ: John Wiley and Sons, Inc.

Eastman, C Teicholz, P and Sacks, R (2012) *BIM Hand Book, 2nd Edition*. Chichester: J Wiley.

Forgues, D, Iordanova, I, Valdivesio, F and French, S (2012) Rethinking the Cost Estimating Process through 5D BIM: A Case Study, *American Society of Civil Engineers*, 787-785.

Gamil, Y and Abdul Rahman, I (2017) Identification of causes and effects of poor communication in construction industry: A theoretical review, *Emerging Science Journal*, 1(**4**), 239-247.

Gee, C (2010) *The Influence of Building Information Modelling on the Quantity Surveying Profession*. BSc (Hons) Study, University of Pretoria, South Africa. Available from https://repository.up.ac.za/dspace/bitstream/handle/2263/16349/Gee_Influence(2010).pdf?sequence=1&isAllowed=y [Accessed 28/07/2019].

Hernández, J L, Lerones, P M, Bonsma, P, Delft, A V, Deighton, R and Braun, J (2018) An IFC interoperability framework for self-inspection process in buildings, *Building*, 8(**2**), 32.

Jennings, M J and Betts, M (1996) Competitive strategy for quantity surveying practices: The importance of information technology, *Engineering, Construction and Architectural Management*, 3(**3**), 163-186.

Junior, A C P, Silva, S L and Pacifico, O (2017) Critical success factors and the iron triangle: A study in project manufacturing environments, *In*: *Proceedings of the International Conference on Industrial Engineering and Operations Management*, Bristol, UK: IEOM Society International.

Kulasekara, G, Jayasena, S and Ariyachandra, M R (2016) Comparative effectiveness of quantity surveying in BIM implementation, *In*: *Proceedings of the 9th International Conference of Faculty of Architecture Research Unit (FARU),* University of Moratuwa, Sri Lanka, 317 - 328.

Kumar, B (2015) *A Practical Guide to Adopting BIM in Construction Projects*. Caithness, UK: Whittles Publishing, 146-3.

Laakso, M and Kiviniemi, A (2012) The IFC Standard - A review of history, development and standardization, *Journal of Information Technology in Construction*, 17, 134- 161.

Latiffi, A A, Brahim, J, Fathi, M S (2015) Roles and responsibilities of construction players in projects using building information modelling (BIM), *In: 12th International Conference on Product Lifecycle Management*. Cham: Springer, 173-182.

Love, P E D, Simpson, I, Hill, A and Standing, C (2013) From justification to evaluation: Building information modelling for asset owners, *Automation in Construction*, 35, 208-216.

Manzoor, K and Gunavel, M (2017) Quantity surveying by Building Information Modelling, *International Journal of Science and Engineering Research*, 5, 1458-1464.

Monteiro, A, Martins, J P (2013) A survey on modelling guidelines for quantity takes off oriented BIM-based design, *Automation in Construction*, 35, 238-253.

Plebankiewicza, E, Zimaa, K and Skibniewski, M (2015) Analysis of the first Polish BIM-Based cost estimation application, *Procedia Engineering*, 123, 405-414.

Proverbs, D G, Holt, G D and Cheok, H Y (2000) Construction industry problems: the views of UK construction directors. *In: A*kintoye, A (Ed.), *Proceedings 16th Annual ARCOM Conference*, 6-8 September 2000, Glasgow, UK. Association of Researchers in Construction Management, Vol. 1, 73-81.

Purnus, A and Bodea, C-N (2015) Financial management of the construction projects: A proposed cash flow analysis model at project portfolio level, *Organization, Technology and Management in Construction*, 1217-1227.

RICS (2015) *Assessment of Professional Competence Quantity Surveying Construction Pathway Guide*. London: RICS.

Seed, L (2015) *The Dynamics of BIM Adoption: A Mixed Methods Study of BIM as an Innovation Within the United Kingdom Construction Industry*. PhD Thesis, Huddersfield University, UK

Smith, P (2016) Project cost management with 5D BIM, Procedia – Social and Behavioural Sciences, 226 193-200.

PROMOTION OF DIFFUSION OF INNOVATIONS: A STUDY OF BIM ADOPTION IN CONSTRUCTION INDUSTRIES

Himal Suranga Jayasena[1], Niraj Thurairajah[2], B A K S Perera[3] and Mohan Siriwardena[4]

[1&3] *Department of Building Economics, University of Moratuwa, Bandaranayake Mawatha, Katubedda, Moratuwa 10400, Sri Lanka*

[2] *Department of Architecture and Built Environment, Northumbria University, Room 108, Sutherland Building Newcastle upon Tyne NE1 8S, UK*

[4] *Department of Built Environment, Faculty of Engineering and Technology, Liverpool John Moores University, Byrom Street, L3 3AF, Liverpool, UK*

With well-known benefits, Building Information Modelling (BIM) is yet to diffuse widely in global construction. Diverse knowledge of BIM adoption from different perspectives has made synthesizing a challenge when devising strategies to promote BIM diffusion. Subjectivity of BIM adoption decision also restricts the generalized strategies. Addressing these problems, the study aims to develop a framework that can be used to efficiently study a context of decision to adopt BIM and inform change agents to help devising appropriate strategies for its diffusion. A Systematic Literature Review is used to develop an affordance-based review framework for BIM adoption decision. The framework is validated by mapping findings from one of the most cited BIM adoption studies to the framework.

Keywords: Affordance, building information modelling, diffusion, innovation

INTRODUCTION

Building Information Modelling (BIM) probably is the most celebrated technological innovation in construction in recent times as has been found in several bibliographic and scientometric analyses (Oraee *et al.,* 2017; Santos *et al.,* 2017; Zhong *et al.,* 2019). This is not surprising when what BIM has brought into the construction industry is considered. BIM has offered solutions for many of the problems the industry has had for decades, if not centuries. It also brings in many enhancements to improve quality, efficiency and effectiveness of construction outputs (Eastman *et al.,* 2011). With many benefits that are communicated through different media, why BIM is yet to become a common practice, is a question among many.

While there were many findings that help understanding of BIM implementation motivators, challenges and barriers, encapsulated knowledge that can be used by change agents to promote 'natural' diffusion of BIM was not evident. Practical application of current knowledge in devising strategies for effective promotion of BIM adoption is also challenged by the diverse findings from different perspectives

[1] suranga@uom.lk

Jayasena, H S, Thurairajah, N, Perera, B A K S and Siriwardena, M (2019) Promotion of Diffusion of Innovations: A Study of BIM Adoption in Construction Industries *In:* Gorse, C and Neilson, C J (Eds) *Proceedings of the 35th Annual ARCOM Conference,* 2-4 September 2019, Leeds, UK, Association of Researchers in Construction Management, 283-292.

and at different levels such as significantly large number of factors affecting BIM adoption (e.g. 20 factors in Buć and Divjak, 2018; 80 factors in Mom *et al.,* 2014). Added to this is the fact that BIM adoption decisions are subjective and are resulting from interplay among many factors internal and external to the potential adopter making universal strategies inapt. Our aim therefore is to develop a framework that can be used to efficiently study a context of decision to adopt (or reject) BIM and inform change agents to help devising appropriate strategies for its diffusion.

METHODOLOGY

The key feature expected of the framework was that it can comprehensively capture a potential adoption context in a manner that can inform a change agent (a) of gaps that limit adoption, (b) of strengths and opportunities that promote adoption, and (c) of neutral features with no effect, because they all are important in devising effective strategies (Oreski, 2012). We started with a Systematic Literature Review (SLR) to review the prominent studies in BIM adoption. The 50 most cited Scopus indexed journal papers published in last five years directly on this subject were found through keyword search for "BIM" or "Building Information Modelling", and "implement", "implementation", "adoption" or "adopt" in their title, keyword or in the abstract. By reviewing the abstracts, the key issues addressed in each were identified. These issues were further studied through a regular review which included other sources (outside of BIM) for better and deeper understanding of the issues. Identified concepts and theories were then critically reviewed so that those can be reduced to be represented in an efficient combination of concepts in a comprehensive framework. We validate the applicability of the developed framework herein by mapping findings from one of the most cited BIM adoption studies to the framework.

The following text explains the rational of arriving at the framework and validation of it. It does not necessarily follow the research process but presents logical flow of facts and propositions.

We identify two prominent works to become valuable because they are reviews of key concept and theories relevant to our work. We found that Ahmed and Kassem (2018) in their paper titled "a unified BIM adoption taxonomy" had reviewed majority of key literature we identified through BIM adoption SLR and follow-up reviews. Thus, it became a valuable source for synthesized knowledge for BIM adoption concepts to be used in our review for clarity and consistency. We use Rogers (2003) for generic definitions and interpretations of Diffusion of Innovations (DOI) because he had encapsulated four decades of diffusion studies in his work. He is the most cited author in DOI studies. All papers we reviewed in this subject had cited him, and many studies had their roots in his work.

Bim Adoption in Construction

BIM in fact is not new. BIM as a concept in construction is nearing a half a century. Design software implementing BIM concept has been in existence for more than thirty years. However, the concept became popular only after the introduction of it by International Alliance of Interoperability in late1990's (Eastman *et al.,* 2011). Yet after more than two decades, universal adoption of BIM to a decent level is yet to be found. We position this problem in Innovation Diffusion studies.

Diffusion of Bim as an Innovation

While it is often mentioned that BIM is an innovation, a clear definition is imperative for consistency. Among number of parallel definitions, we cling to Rogers:

Innovation is "an idea, practice or object perceived as new by an individual or other unit of adoption" (2003, 12). The term "unit of adoption" emphasizes the subjectivity of what an innovation is. For the purpose of adoption, if an idea is in fact new objectively has only a small effect. What matters is the perceived novelty of the idea. Novelty is not purely about new knowledge either. Novelty is identified at the point of decision to adopt, that if what is to be adopted is new. This interpretation of innovation matches with the status of BIM as a novel approach to construction project delivery, and with the fact that what is new in BIM is user and context dependant.

BIM diffusion studies as of date have focused on diverse subjects, including but not limited to (1) barriers, (2) cultural issues, (3) maturity and awareness, (4) change, (5) drivers and (6) diffusion prediction (Ahmed and Kassem, 2018). While these studies present both wide and deep understanding of BIM adoption and diffusion, our cognition capacity limits the formulation of effective and efficient promotional strategies in absence of a concise fit-all-in-one framework that can hold all relevant knowledge.

Diffusion and adoption are highly related but different in meaning. Diffusion as a generic concept is defined as "spreading [of] something widely in all directions" (Oxford Advance Learner's Dictionary, 2000, 349). This definition is directly applicable to the context of this study, because, to study how innovations, such as BIM, spread in an industry is within its wider scope. Accordingly, "diffusion" is about the innovation and "adoption" is about the user. How an innovation is diffused is by the adoption of it by users. We will not count mere implementation into diffusion, because implementation can also occur at trial and experiment level.

One may find that two terms - adoption and implementation are often confused and used interchangeably in BIM diffusion studies. For clarity and consistency, we would maintain that adoption is "a decision to make full use of an innovation as the best course of action available" (Rogers, 2003, 177) and Implementation "occurs when an individual put [the innovation] into use" (Rogers, 2003, 169). Following these definitions and interpretations can also become helpful because the large majority of BIM adoption/diffusion studies are based on theory of Diffusion of Innovation (DOI) by Rogers (2003). Other theories popularly adopted in BIM diffusion studies are Institutional Theory (INT), Technology Acceptance Model (TAM) and Theory of Reasoned Action (TRA). These theories also use compatible taxonomies (Ahmed and Kassem, 2018).

Theories of BIM Adoption

Among the popularly used theories, DOI is the theory that can and to a good extent has been used to most expansively describe the diffusion of BIM (Buć and Divjak, 2018). This is expected because it has been applied also in many different contexts (outside of BIM), especially in the diffusion of information and communication technologies in different fields (Lievrouw, 2014).

DOI comes under communication studies and it addresses diffusion from different foci. It identifies the effect of social system, especially its structure and norms, on diffusion. Then it looks at the role of key players, viz. change agents, their aide, and opinion leaders in the community. Communication channels is another focus of the theory. Diffusion time is addressed from three foci. Individual members' innovativeness is modelled using cumulative number of adopters and in the community in concern. It explains the innovation decision process over the timeline on how an individual comes to the ultimate decision if to adopt or reject the

innovation. It also identifies innovation's rate of adoption as a personal property of innovation. It defines and links diffusion to four types of innovation decisions as optional, collective, authority and contingent (Rogers, 2003). These areas are variably addressed in present BIM diffusion studies, though some may not explicitly link their findings to DOI concepts and principles (Ahmed and Kassem, 2018).

Another focus of DOI is on the innovation itself. This in fact covers many different aspects. One key area is the perceived characteristics of the innovation (Buć and Divjak, 2018). This includes compatibility, complexity, trialability, observability and relative advantage. Relative advantage is considered from both social and economic perspectives, and also in terms of positive and negative incentives. Types of innovations are considered in terms of tech vs. non-tech, incremental vs. preventive and interactive vs. non-interactive. Re-invention, a feature of innovation explaining the "degree to which an innovation is changed or modified by a user in the process of its adoption and implementation" is also identified as an important point in innovation decision process introduced earlier (Rogers, 2003). BIM diffusion studies have limited focus on effect of innovation, i.e. BIM, on its diffusion (Ahmed and Kassem, 2018). A deep enough study that recognizes the effect of innovation packaging of BIM on its diffusion was not found.

Institutional theory suggests "diffusion dynamics in which external isomorphic pressures motivate organisations to perform behavioural and structural changes while seeking to acquire social legitimacy" (Ahmed and Kassem, 2018, 106). Even though it takes a seemingly different perspective to diffusion, its essence could be understood within DOI that it also has its roots in "imitation" (Marquis and Tilcsik, 2016). The Technology Acceptance Model (TAM) also covers (but goes into detail) one of the foci of DOI. In its original version, Davis (1989) developed and validated new scales for two specific variables, perceived usefulness and perceived ease of use, which he hypothesized to be fundamental determinants of user acceptance. The model was later developed by Venkatesh and Davis (2000) by incorporating subjective norm (one's perception what others think one should do), image, job relevance, output quality, and results demonstrability; and was recognized as TAM2. As next step, TAM3 has been proposed adding emotions theory, such as anxiety and enjoyment, and perceived risks of adoption as technology acceptance predictors (Venkatesh and Bala, 2008).

In one of the most cited BIM adoption studies from recent years, Volk *et al.,* (2014) identify that the scarce use of BIM for existing buildings was due to technological limitations. In another popular study authors state that "BIM refers to a combination or a set of technologies and organizational solutions that are expected to increase interorganizational and disciplinary collaboration in the construction industry and to improve the productivity and quality of the design, construction, and maintenance of buildings" (Miettinen and Paavola, 2014, 84). Wu *et al.,* (2016) ascertain that BIM not being used to its potential to be a critical limitation to use 3-D printing of buildings. Some studies focus on developing technological systems to solve problems or to improve practice, and they seem to believe that to be the role of technology (Fisher, 2012). Presenting a study on developing a framework for post-construction energy efficiency, the GhaffarianHoseini *et al.,* take the position that "Integrated Knowledge-based Building Management System using nD BIM applications (nD BIM-IKBMS) is expected to provide simulation-based supervisory control while automatically detecting and diagnosing operational faults" (2019, 13). Consequently, it becomes evident that most BIM diffusion researchers have taken technological deterministic stance in their studies that "BIM technology is given" or

"BIM can make the things happen", and many shows possible pro-innovation biases that "BIM must be adopted". This does not mean that they took hard technological determinism; and of course, often they had a mixed approach.

Technological determinism has traditionally been a dominant theory in science and technology studies in understanding the role of technology on society. However, the introduction of Social Construction of Technology approach in 1990's "encouraged communication technology researchers to reject technological determinism in favour of a view of technology as socially constructed" (Lievrouw, 2014, 22). These initiatives mingled also with BIM studies. Some studies had been built upon quite strong social constructive approaches. For example, Linderoth *et al.,* (2014) use the concept of boundary objects to study how BIM can facilitate knowledge and expertise sharing to minimize design errors.

Showing that neither strong determinism nor social constructivism of technology are the way forward to understand diffusion, Lievrouw recommends capturing multifaceted complexity of technology by taking their "materiality, cultural significance and meaning, the values and power they represent, institutional interests that advance them, and attitudes and motivations of their users" (2014, 50). Among these, materiality is the key concept to represent technological determinism.

Materiality of BIM

Materiality of an entity is the "character of [entity] that makes them useful and useable" (Lievrouw, 2014, 25). Although materiality has already been identified as useful for meaningful understanding of adoption of technologies, it has rarely been used by BIM researchers.

Paavola and Miettinen study "BIM models as co-developed intermediary objects in the design [and] suggest that BIM models provide novel forms of virtual materiality" (2018, 1113). The study was not on BIM diffusion, but it was the only BIM study we found materiality concept being identified as keyword and deeply reviewed. Many had used the architectural concept of materiality to represent the BIM objects' property "(building) material", making them irrelevant to this study. It is not that materiality was not a concern of researchers, it is only that they failed to recognize materiality as a useful concept. For example, even though Fisher (2012) does not mention materiality in his paper on real-time approaches to performative computational design, his preface writer finds that Fisher links model capabilities to materiality of design.

Materiality, though not explicitly recognized, has of course been used by many BIM researchers through different means. The materiality of BIM is regularly represented in "BIM function" or in "BIM uses", which of course found in large majority of, if not all, BIM adoption/diffusion studies. However, the wholistic view of materiality, i.e. what is material and what is not, is absent in these studies.

Within the complexity of technology to be understood, its materiality is at a pivotal position, because it is what enables the use of technology. Social factors previously identified blends with materiality to develop social meanings to technology, which ultimately leads to adoption or rejection of new technology or the innovation. (Lievrouw, 2014; Rogers, 2003). Wyche *et al.,* (2019) use the concept of "affordance" study this complexity in mobile phone technology.

Affordances

Affordance has been a widely used concept in multiple domains of research including computer software, communication studies, engineering design and sociology since its first introduction by Gibson to ecological sciences four decades ago. Gibson coined the word "affordance" explaining "affordances of the environment are what it offers the animal, what it provides or furnishes, either for good or ill [and that affordance] implies the complementarity of the animal and the environment" (Gibson, 1979, 127). A decade later, Norman (1988) introduced and popularized the concept among designers because it helped them understand how their products would be used. The concept is widely used in computer software development, especially in their graphical user interfaces (GUIs), e.g. a button image to click; but also, in designing of physical objects, e.g. a door a handle to pull or a knob to turn (Wyche *et al.,* 2019).

Identifying a confusion of the use of concept, Norman later expanded the concept into two (1) real affordances and (2) perceived affordances. Real affordance is affordance "offered by artefacts that can be acted upon or physically manipulated for a particular purpose" (Hartson, 2003, 317). Real affordances in fact is equal to Gibson's original concept that "an affordance exists relative to the action capabilities of a particular actor, [and it exists] independent of the actor's ability to perceive it" (McGrenere and Ho, 2000, 179). Therefore, it is independent of the needs of the user. Perceived affordance, on the other hand, is affordance that is perceptual to the user, or the actions a user perceives to be possible (Wyche *et al.,* 2019). Norman believed "[perceived] affordances result from the mental interpretation of things, based on our past knowledge and experience applied to our perception of the things" (1988, 2019). Accordingly, a perceived affordance can exist without real affordance.

After reviewing theories in and around materiality, technological determinism and social constructivism of technology, Lievrouw also had suggested to use affordance because it "offers a reconciliation between the opposing poles of constructivism and realism" (2014, 48). By complexifying affordance with Innovation Decision Process of DOI (refer Rogers, 2003), a conceptual framework to study and understand how materiality of an innovation affects its adoption can be developed.

In order to do this, we first define "expected affordances", a simple concept to represent the expectation of an adopter of an innovation. This is not synonymous with "imagined affordances". These are affordances an adopter will look for when considering an innovation. We scope expected affordance to be within functional affordances (as introduced by Hartson, 2003) to represent (expected) real affordances that carry utility or purpose, because use (represented by affordance in here) without a utility or purpose is not material in innovation decision (Rogers, 2003). Like perceived affordances, expected affordances also are subjective, dynamic and evolving. Intersections and relative complements of three sets of affordances viz. (1) expected, (2) real and (3) perceived, make seven types of affordances as shown in Table 1. This is proposed as a framework to study innovations such as BIM to obtain concise yet satisfactory knowledge about the innovation to device effective strategies to promote its adoption.

To come up with the nomenclature, we also bring concepts from Gaver (1991) (1) Perceptible Affordances - real affordances that are also perceived, (2) False Affordance - perceived affordances that are not real, and (3) Hidden Affordances - real affordances that are not perceived. Our use of term Material Affordances is slightly different to Hutchby (2001), where we mean that these affordances are

material in correct adoption. Strategies for addressing the conditions are identified by synthesising from theory of Diffusion of Innovation (Rogers, 2003).

The framework may not be used in isolation for effective results. It should be understood by relating to existing DOI theories. For example, how homophily and heterophily play a role in interpersonal communication will offer deeper understanding of Critical False Affordances. What framework offers is an efficient method to identify the status of innovations or critical conditions that needs or needs not to be addressed to promote diffusion of innovations.

Table 1: Seven Types of Affordances affecting Innovation Decision

Nr.	Type	Name and description	Significance and strategies
1	Expected, real and perceived	"Material Affordances" are Perceptible Affordances within expected functionalities	Significant positive impact leading to adoption. No strategies are expected, except assuring of status quo
2	Expected, real but not perceived	"Critical Hidden Affordances" are Hidden Affordances within expected functionalities	Negative impact leading to false rejection before implementation. Mass media and commercial change agents
3	Expected, perceived but not real	"Critical False Affordances" are False Affordances within expected functionalities.	Significant negative impact leading to false acceptance for implementation and eventual rejection. Opinion leaders, community organization and authorities to communicate
4	Expected, but neither real nor perceived	"Missing affordances" are the expected functionalities not offered	Positive impact leading to correct rejection. No direct positive impact to diffusion. But passive impact by minimizing conclusion "the innovation is a failure" No strategies are expected, except assuring of status quo
5	Not expected, but real and perceived	"Windfall affordances" are Perceptible Affordances outside of expected functionalities.	Nice to have perks of adoption will strengthen the Material Affordances. Overemphasis by change agents and media may increase Hidden Affordances and Waste. Limit communication to mass media. Create needs
6	Neither expected nor real, but perceived	"Noncritical False Affordances" are False Affordances outside of expected functionality	Neutral effect yet with risk of developing into Critical False Affordance Opinion leaders, community organization and authorities to communicate
7	Neither expected, nor perceived but real	"wasted affordances" are hidden affordances outside of expected functionalities	Neutral effect. Overemphasis by change agents and media may reduce Material Affordances. Limit communication to mass media.

BIM Affordances

Though not popular, affordances of BIM have got attention of few authors. Pärn *et al.,* identify "functional affordances of BIM and how they influence the architectural design process" (2015, 331). Merschbrock (2013) explore BIM's current use and affordances. The study highlights the researchers' interests in linking affordance to use. Yet, findings are not comprehensive enough to validate the framework proposed herein (in Table 1).

The value of the developed framework to study BIM with its promotion in mind is vindicated by the statement by Miettinen and Paavola: "although BIM visions and

promises are needed for BIM implementation, they need to be complemented with a more realistic view of conditions of the implementation… in addition to standards and guidelines underlined by normative approaches, local experimentation and continuous learning play a central role in the implementation of BIM" (2014, 84).

In order to validate the applicability of our framework (presented in Table 1) to review a context of BIM adoption, we use the most cited publication with "BIM Adoption" in title - Understanding and facilitating BIM adoption in the AEC industry by Gu and London (2010; cited 283 in SCOPUS, 592 in Google Scholar). By relating and contrasting its conclusions of this study, we review how far our framework can capture and contain knowledge therein. We extract only the key or leading text below. Referring original publication is required for deeper understanding.

> 6.1. In terms of product - Expectations from BIM vary across disciplines. Design see BIM as an extension to CAD, contractors and project managers expect BIM to be a more intelligent DMS …" confirms the importance of Expected Affordances. Authors go onto say "Our desktop audit suggests BIM applications are not yet completely mature for [this] purpose". Showing the gap in real affordances, they point that BIM application vendors aim to integrate expectations of two groups keeping both parties long with Missing Affordances, and probably trying to market BIM applications using Windfall Affordances or even Wasted Affordances. Had the affordances been studied using our framework, vendors would have had better systematic knowledge on industry needs, and they could have packaged their developments accordingly.
>
> 6.2. In terms of process - BIM adoption would require a change in the existing work practice…" This conclusion is about the adopter, where our framework is about the Innovation. Therefore, this is not represented in it, but as highlighted, using our framework along with current diffusion theories will address these requirements.
>
> 6.3. In terms of people - … numerous factors affecting BIM adoption, mainly fall into two: technical tool functional requirements and needs, and nontechnical strategic issues". Value of our framework for the first is obvious. The second is elaborated as "where to start, what tools are available and how to work through the legal, procurement and cultural challenges…"; and it highlights that Expected Affordances are not purely technological in nature. Our framework will identify these affordances of which the interests will primarily be outside of application vendors, but will be with those with authority, leaders and change agents.

Accordingly, our framework can holistically encapsulate the knowledge that is required to strategically package BIM, both technologically and procedurally, for its effective diffusion.

CONCLUSIONS

Affordance based review of innovations will offer concise yet satisfactory knowledge to device effective strategies to promote innovation adoption. The framework we developed through this review (refer Table 1) is recommended to study the status quo of BIM in adopter groups to help devising appropriate strategies for effective diffusion of BIM. Basic theoretical strategies are identified in this framework, real-life application would lead robust and unique strategies that can contribute to knowledge.

The framework may not be applicable to innovators because of their unique characteristics of innovations adoption. However, we see no limitations in its applicability to other adopter groups including early adopters. Further, the framework was developed in a manner to minimize the possibility of pro-innovation biases. Endeavours requiring such biasness, e.g. commercial BIM promotion, would require adjustments to the framework.

REFERENCES

Ahmed, A L and Kassem, M (2018) A unified BIM adoption taxonomy: Conceptual development, empirical validation and application, *Automation in Construction*, 96, 103-127.

Buć, S and Divjak, B (2018) Key factors of an organization's environment for the acquisition and assimilation of an innovation, *Journal of Information and Organizational Sciences*, 42(**1**), 17-37.

Davis, F.D (1989) Perceived usefulness, perceived ease of use and user acceptance of information technology, *MIS Quarterly*, 13(**3**), 319-340.

Eastman, C, Teicholz, P, Sacks, R and Liston, K (2011) *BIM Handbook: A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers and Contractors, 2nd Edition*. Hoboken, NJ: Wiley,

Fisher, A (2012) Engineering integration: Real-time approaches to performative computational design, *Architectural Design*, 82(**2**), 112-117.

Gaver, W W (1991) Technology affordances, *In*: *CHI '91 Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, New Orleans, Louisiana, USA, 79-84.

GhaffarianHoseini, A, Zhang, T, Naismith, N, GhaffarianHoseini, A, Doan, D.T, Rehman, A.U, Nwadigo, O and Tookey, J (2019) ND BIM-integrated knowledge-based building management: Inspecting post-construction energy efficiency, *Automation in Construction*, 97, 13-28.

Gibson, J J (1979) *The Ecological Approach to Visual Perception*. Harcourt, Boston, MA: Houghton Mifflin.

Gu, N and London, K (2010) Understanding and facilitating BIM adoption in the AEC industry, *Automation in Construction*, 19(**8**), 988-999.

Hartson, R (2003) Cognitive, physical, sensory and functional affordances in interaction design, *Behaviour and Information Technology*, 22(**5**), 315-338.

Hutchby, I (2001) Technologies, texts and affordances, *Sociology*, 35(**2**), 441-456.

Lievrouw, L A (2014) Materiality and media in communication and technology studies: An unfinished project, *In*: Gillespie, T, Boczkowski, P J and Foot, K A (Eds.) *Media Technologies: Essays on Communication, Materiality and Society 1st Edition*. Cambridge, Massachusetts: The MIT Press.

Linderoth, H, Johansson, P and Granth, K (2014) The role of BIM in preventing design errors, in Raiden, A B and Aboagye-Nimo, E (Eds.), *Proceedings of the 30th Annual ARCOM Conference*, presented at the 30th Annual ARCOM Conference, Association of Researchers in Construction Management, Portsmouth, UK, 703-712.

Marquis, C and Tilcsik, A (2016) Institutional equivalence: How industry and community peers influence corporate philanthropy, *Organization Science*, 27(**5**), 1325-1341.

McGrenere, J and Ho, W (2000) Affordances: clarifying and evolving a concept, *In*: M McCool (Ed.) *Proceedings of Graphics Interface 2000*, Canadian Human-Computer Communications Society, Montreal, Canada, 179-186.

Merschbrock, C (2013) Affordances of Building Information Modeling in Construction: A Sequential Analysis, *In*: *International Council for Research and Innovation in Building and Construction (CIB) World Building Congress*, Brisbane, Australia.

Miettinen, R and Paavola, S (2014) Beyond the BIM utopia: Approaches to the development and implementation of building information modelling, *Automation in Construction*, 43, 84-91.

Mom, M, Tsai, M.-H and Hsieh, S.-H (2014) Developing critical success factors for the assessment of BIM technology adoption: Part II Analysis and results, *Journal of the Chinese Institute of Engineers*, 37(**7**), 859-868.

Norman, D A (1988) *The Psychology of Everyday Things*. Paperback Book Club edition/ Basic Books Inc.

Oraee, M, Hosseini, M R, Papadonikolaki, E, Palliyaguru, R and Arashpour, M (2017) Collaboration in BIM-based construction networks: A bibliometric-qualitative literature review, *International Journal of Project Management*, 35(**7**), 1288-1301.

Oreski, D (2012) Strategy development by using SWOT - AHP, *Technology Education Management Informatics*, 1(**4**), 283-291.

Oxford Advanced Learner's Dictionary (2000) *Oxford Advanced Learner's Dictionary 6th Edition*. Oxford: Oxford University Press.

Paavola, S and Miettinen, R (2018) Dynamics of design collaboration: BIM models as intermediary digital objects, *Computer Supported Cooperative Work*, 27(**3-6**), 1113-1135.

Pärn, E, Colombage, L, Thurairajah, N and Ahmed, V (2015) Affordances of BIM during the architectural design process, *In*: *12th International Post-Graduate Research Conference*, University of Salford, MediaCity, UK, 331-341.

Rogers, E M (2003) *Diffusion of Innovations 5th Edition*, New York: Free Press.

Santos, R, Costa, A A and Grilo, A (2017), Bibliometric analysis and review of building information modelling literature published between 2005 and 2015, *Automation in Construction*, 80, 118-136.

Venkatesh, V and Bala, H (2008) Technology acceptance model 3 and a research agenda on interventions, *Decision Sciences*, 39(**2**), 273-315.

Venkatesh, V and Davis, F D (2000) A theoretical extension of the technology acceptance model: Four longitudinal field studies, *Management Science*, 46(**2**), 186-204.

Volk, R, Stengel, J and Schultmann, F (2014) Building Information Modeling (BIM) for existing buildings - Literature review and future needs, *Automation in Construction*, 38, 109-127.

Wu, P, Wang, J and Wang, X (2016) A critical review of the use of 3-D printing in the construction industry, *Automation in Construction*, 68, 21-31.

Wyche, S, Simiyu, N and Othieno, M E (2019) Understanding women's mobile phone use in rural Kenya: An affordance-based approach, *Mobile Media and Communication*, 7(**1**), 94-110.

Zhong, B, Wu, H, Li, H, Sepasgozar, S, Luo, H and He, L (2019) A scientometric analysis and critical review of construction related ontology research, *Automation in Construction*, 101, 17-31.

COLLABORATION

APPLICATION OF SIGNALLING THEORY IN CONTRACTOR SELECTION FOR LONG-TERM COLLABORATIVE RELATIONSHIPS IN CONSTRUCTION

Calistus Ayegba[1] and David Root

School of Construction Economics and Management, University of Witwatersrand, Witwatersrand, Braamfontein, Johannesburg, 2000, South Africa

Contractor selection for long-term collaborative relationships will involve carrying out a behavioural assessment of potential contractors to establish their competencies for collaboration and long-term relationships. People behavioural characteristics such as their trustworthiness, emotional states, genuineness, innate abilities and their possibility of acting in an expected way in the future are often challenging to evaluate in a physical encounter directly. In this study, the exact observable signals that indicate a contractor's suitability for long-term collaborative relationships were empirically investigated from the client's organisations point of view, employing signalling theory. Data was collected using semi-structured interviews with eight purposively selected organizations involving sixteen key informants in South Africa. The significant signals which are perceivable indicators of contractor's suitability for collaboration and long-term relationships from the findings are: Past-performance signals; commitment signals which not only concerns attendance but also contractor's willingness, participative contributions and top management involvement in the various activities during the selection processes; and behaviour signal which comprises of being polite, honest, respectful and realistic. The study result represents a significant contribution to knowledge and understanding that are useful in identifying required signals to be sought in contractors for realistic evaluation, and ultimately make a better decision in selecting an appropriate contractor for long-term collaborative relationships. This study thus makes a strong case in providing theoretical explanations of contractor selection practices to accommodate for long-term collaborative relationships from a signalling theory perspective.

Keywords: collaboration, contractor selection, long-term relationships, signalling

INTRODUCTION

The selection of a suitable contractor is critical to the success of any construction project (San Cristóbal, 2012; Doloi, 2009). Thus, several studies exist on contractor selection and the traditional evaluation methods. In contractor selection for long-term collaborative relationships, the behavioural assessment of potential contractors to establish their competencies for collaboration and long-term relationships is essential. However, it is difficult to discern or assess the behaviours of people or organisations. Notably, as it will have to do with considering intangible attributes such as honesty, openness, genuineness, commitment and people possibility of acting in an expected

[1] buildercally@yahoo.com

Ayegba, C and Root, D (2019) Application of Signalling Theory in Contractor Selection for Long-Term Collaborative Relationships in Construction *In:* Gorse, C and Neilson, C J (Eds) *Proceedings of the 35th Annual ARCOM Conference,* 2-4 September 2019, Leeds, UK, Association of Researchers in Construction Management, 294-303.

way in the future. In contrast, contractor selection practices in the traditional contracts which most people are used to, only consist of evaluating written and oral submissions (Dewberry *et al.,* 2018) and considers more of hard attributes such as time, price, quality and resources.

This is not to say these hard attributes are not relevant when selecting contractors for long-term collaborative relationships but will be inadequate to cover all the issues upon which to select a suitable contractor for long-term collaborative relationships. In addition, for long-term collaborative relationships, assessing the behaviours of potential contractors is required (Dewberry *et al.,* 2018). However, owing to the difficulty to directly quantify and evaluate people or organisations behaviour for assessment in a physical encounter, one will need to apply signalling theory and rely on signals thought to correlate with the underlying attributes to be able to establish contractor's competencies for long-term collaborative relationships. Signalling theory helps to explain how one can make a decision relying upon signals, which are perceivable indicators of non-directly observable qualities. Therefore, the theory provides a lens to explore the signals that offer an opportunity for identifying required attributes for long-term collaborative relationships in a contractor selection process.

LITERATURE REVIEW

The Evolution of Long-Term Collaborative Relationships in Construction

Long-term collaborative relationship practices are increasingly being adopted globally, owing to its success in the manufacturing and service sectors, where the strategies are seen as a vehicle to maximise value, levels of quality, and service delivery (Khalfan *et al.,* 2014; Frödell, 2011; Baiden and Price 2011). In construction, the interest in long-term collaborative relationships is attributed to the industry's response to the failings of traditional contracting practices. Also, the influence of the Latham 1994 "constructing the team" and Egan 1998 "rethinking construction" UK construction industry reports together with other construction industry reports from Hong Kong, New Zealand, and Singapore are credited to have influenced the rising trend of collaboration and long-term relationship practices in the construction industry (Kamudyariwa *et al.,* 2018). The approach has been shown to be mutually beneficial to both clients and contractors when adopted for project delivery.

Long-term collaborative Relationship involves an arrangement that brings together the concept of collaboration and long-term relationships. Table 1 shows long-term collaborative practices. As evidenced in Table 1, long-term collaborative relationships requirements are indicated to focus on creating an enabling environment that optimises the ability of project team members to work together efficiently and collaboratively. Thus, building a long-term business relationship through which a series of projects can be delivered successfully without litigation. This is a fundamentally different situation from what is sought in the traditional contracting practice of one-tender-per-project approach, where the client enters into a contractual agreement and assembles a separate supply chain for each project, with short-term relationships, and a consequent concentration of knowledge within the design team only (Ruparathna and Hewage, 2015; Watermeyer, 2012). Such practices are said to often result in significant opportunities for claims and inappropriate risk avoidance, and, consequently, adversarial relationships and litigation processes (Watermeyer, 2012).

Table 1: Long-term Collaborative Relationship Requirements

Author(s) and year	Long-term Collaborative Relationship Requirements
Sanchez (2012)	- Having shared goals - Being involved in the process - Having open lines of communication - Directed engagement
Babaeian *et al.,* (2016)	- Trust - Commitment - Teamwork - Open communication - Common goals between partners - Fair balance of risks and rewards - Consistent objectives - Mutual trust - Clear contract - Clear decision-making mechanism - Clear understanding of responsibilities
Frödell (2011)	- Willingness and capability for collaboration - Aligned core values - Parties to be approachable, honest, and responsive - Total cost focus - Knowledge, along with delivery precision - Trust - Long-term orientation
Suprapto *et al.,* (2015)	- Commitment - Teamwork - Co-operation - Relational attitudes - Capability - Team integration - Connectedness of owner and contractor striving for a common goal

Signalling Theory

Signalling theory helps to explain how one can make a decision relying upon signals, which are perceivable indicators of these not directly observable qualities. The core idea of signalling theory has its root in the writings of Thorstein Veblen, "The Theory of the Leisure Class" in 1899. Thorstein Veblen used the principle of signalling theory to explain 'wasteful' human practices, by suggesting that the conspicuous consumption and wasteful spending of the wealthy served as a signal of their status as elite.

In economics, based on the earlier work of Akerlof (1970) who argued that without signals of product quality, product markets would not exist as there will be little information to distinguish low quality from high-quality products. Spence (1973) indicates that signals are essential sources of information in the case of information asymmetry when information that is more objective is unavailable. In explaining the role of education as a signal in employer-employee relationships using signalling theory, Spence argues that since the cost of the opportunity, which is the sum of time, tuition and effort spent on education, is a good indicator of performance, the level of education is correlated with better work performance. Therefore, employers use the level of education as a signal that helps differentiate low-quality applicants from high-quality applicants for job selection. Thus, the use of signalling theory helps mitigate the potential for adverse selection.

Application of Signalling Theory and its Relevance to this Study

As illustrated from the preceding, signalling theory is a vital theory employed across a wide range of research context, and it is indicated to be genuinely interdisciplinary. Gambetta (2008) posits that the signalling theory is the fastest developing theory across all behavioural sciences in recent times. The theory is used to identify the range of potential signals and the contexts in which signalling occurs to provide explanation and solution to the influence of information asymmetry and uncertainties.

Its application covers varieties of subject areas and disciplines such as human courtship, commercial advertising, entrepreneurship other business contexts, religion, and animal communication. Others include Human resource management/job market context, sells of equities /online auction, economics, social networks, sports and sociology. Virtually in every relationship and endeavour, people rely on the application of signalling theory, especially when dealing with characteristics that are unobservable or difficult to perceive directly. Donath (2011: 1) well illustrates this in her write up:

> A bird wants to know if the butterfly it is about to eat is poisonous before it takes a bite, and relies on the signal of wing markings to decide whether to eat or move on. An employer wants to determine before making a hiring decision whether a candidate will be successful or not and relies on signals such as a resume, references, and the candidate's actions and appearance to predict suitability for the job. A smile can be a signal of happiness, a wedding ring a signal of being married, smooth skin a signal of youth, and a big house a signal of wealth. ……Indeed, much of our communication, whether it is with words, gestures, or displays of possessions, consists of signalling information about who we are and what we are thinking.

Bergh *et al.,* (2014) opines that the increasing adoption of signalling theory in management research is because the theory addresses the core problems of how strategic decision maker can use signals to reduce the uncertainty associated with making a selection among a choice set and situations where there is information imbalance between parties (information asymmetry). It is employed in decision-making problems as decision-makers rely on signals to avoid exploitation, to mitigate the potential for moral hazard and adverse selection, to decide whether to trust a person and to persuade others of one's trustworthiness (Gambetta and Hamill, 2005; Janney and Folta, 2006; Gambetta, 2008).

The underlying principles behind signalling theory describe the reliance on signals at an initial encounter with a signaller to solve problems of uncertainty and asymmetry of information when making choice decisions. There has been a strong case for the application of signalling theory at pre-contractual stages when decision makers decide on one's trustworthiness so as to mitigate the problems of adverse selections. For example: McNally (1995) who focuses on the signals to the pre-announcement of equities; Bulbulia and Sosis (2011) who looks at the signals to pre-committing members as indication of cooperative futures; and Mavlanova *et al.,* (2012) whose study was on pre-purchased signals in online retails examines the effect of signals on purchase intentions before the actual transaction takes place. These studies suggest that both high- and low-quality sellers rely on pre-purchased signals to indicate quality and to motivate buyers to transact. Consistent with the fundamental principles of signalling theory, this study seeks to determine the signals to look out for when selecting contractors for long-term collaborative relationships.

RESEARCH METHOD

Data for the study was elicited from the narrative experience of key informants of eight organizations in South Africa via semi-structured interviews. As typical to qualitative research methodology, participants are allowed to provide data in their own words and meanings will be informed from their point of view in line with the interpretivist philosophy (Saunders *et al.,* 2012). Sixteen key informants from the eight organisations which were purposively selected took part in the study. The key informants (comprising of directors, project managers, chairperson and executive managers) who took part in the study, do represent a diverse set of representatives

with different positions and from a wide range of backgrounds and experience in construction procurement, framework contracts and in the selection of contractors for framework contracts. The characteristics of the key informants who participated in the study conform to the suggestions for selecting key informants by Kumar (1989) and Marshall (1996). The organizations are then coded using the pseudonyms Alpha 1 to Alpha 8. The Key informant interviews involve interviewing people, who are selected for their first-hand knowledge about a topic of interest and are likely to provide needed information, ideas, and insights on the topic of interest (Kumar 1989; Marshall, 1996).

The interviews were audio recorded to ensure that all information was captured during the interviews. Also, brief notes were taken during the interviews to capture both verbal and nonverbal signals from the key informants. The audio record was transcribed verbatim. The data collected from the key informant interviews were analysed with the aid of the Nvivo 11 pro qualitative data analysis software for windows and following thematic qualitative data analysis methodology outlined by Miles, Huberman and Saldana (2014). The result of the qualitative analysis of the data collected was presented using a word cloud resulting from the word frequency query with the aid of Nvivo 11 pro qualitative data analysis software. The word cloud provides a synopsis of the main themes and a sense of the emerging pattern within the set of data. Also, supporting direct quotes from the key informants (consent was obtained to use key informants' direct quotes) was used in reporting the data of the study.

FINDINGS AND DISCUSSIONS

The data encompassing signals that encourage and indicates a contractor's suitability for long-term collaborative relationships were elicited from the key informants of the organizations under study. Figure 1 shows the prominent words across the data on the signals that encourage and indicates a contractor's suitability for long-term collaborative relationships. These are past-performance which consists of vetting with references, commitment including top management involvement, and active, participative involvement, quality of people and submissions, and willingness to participate. Others are related to behaviours characteristics such as openness, honesty, respect, and being realistic.

In a contractor selection process for long-term collaborative relationships, there may be increased information asymmetry between the clients and the potential contractors. Mainly as the appropriate attributes for long-term collaborative relationships are more of intangible attributes which are not quantifiable or can be measured directly. Signalling theory argues that when the attributes of an organisation or people cannot be directly observed, decision-makers must rely on signals thought to correlate with the underlying attributes (Drover *et al.,* 2018; Spence, 1974). Therefore, following the principles of signalling theory, this section will discuss what specific signal indicates the contractor's selection suitability for long-term collaborative relationships. Following a test run on each of the displayed words in Figure 1 to unravel the context and meanings using the Nvivo 11 pro software, the signals that encourage and indicate a contractor's suitability for long-term collaborative relationships are discussed below:

Figure 1 Word Cloud Depicting Prominence Words on Signals that Encourages and Indicates the Contractor's Suitability for Long-Term Collaborative Relationships.

Past-Performance Signalling

Signalling based on past-performance on previous jobs accounts for the display of the three words: ‘references', ‘records' and ‘previous' in the word cloud (Figure 1). Virtually all the organisations indicated Past-performance signals via their key informants as a vital signal that indicates a contractor's suitability for long-term collaborative relationships in a framework contract. To quote from the key informant's interview transcript:

> The only signal is when we cross-reference based on the previous job that they actually did. It is something that is abstract more than anything. It is difficult to measure that in the selection process. However, when you look at his previous track records and previous jobs, it can show this person has got the following attributes and character basically for collaboration and long-term relationships. So, we get CV's, ask them for three references, from the references we can deduct some information on whether to use them or not. Remember, all of them will tell you that they are fit for the job. Alpha7

Past-performance is indicated among the three primary criteria with the other two being financial stability and experience (out of 20 decision factors and 67 sub-factors for contractors' pre-qualification) for contractor selection decisions (Russell *et al.,* 1992). Since the attributes for long-term collaborative relationships are intangible and cannot be discovered directly by observation, contractor's past-performance serves as the best indicator of future performance in regarding long-term collaborative relationship attributes of contractors. It reduces the degree of uncertainties about the quality of potential contractors. Although it's not uncommon for a contractor who has performed well collaboratively in previous jobs to suddenly act out of character.

Commitment signalling

The process of selecting contractors for long-term collaborative relationships comprises of several stages including meetings, workshops and competitive dialogues (Ayegba and Root, 2018). The findings from across the data show that contractor’s commitments in all the tendering processes are an important signal that indicates a contractor's suitability for long-term collaborative relationships. Quoting from the key informant's interview transcript:

> It's subjective. Willingness to participate and present in all process and meetings... my common sense tells me that if a person is not keen to do a particular type of work, it's

> going to come through in the way his tender is prepared. You will pick it up as an experienced evaluator. Alpha 6

> Participatory involvement, if the contractor wasn't scared of telling the consultants to look at something in another way. Top management involvement, if their director was sitting in all our meetings from day one and he is a fairly knowledgeable person. Alpha 1

Therefore, Commitment signals concern not only attendance but also the contractor's willingness, participative contributions, the standard of tender and top management involvement in the various activities during the selection processes. The significant of top management involvement is such that can produce a skewed result against bigger contractor organisations with higher cidb grade level, in contrast, to lower cidb grade contractors whose top management are involved in selection processes as illustrated by Alpha 6:

> Do they have the right commitment? The best results often come from smaller contractors. We have had Grade 7s and 8s and 9s on both sides. The problem when you sit with a grade 9 is that it is a big corporate organisation…so have a big disjuncture between tendering and execution. You come to a grade 7 or 8 contractors, the guy sitting in front of you is the guy intimately involved in the tender and the execution, and he is the decision maker. So, the relationship with them is better. Alpha 6

According to Alpha 1, a commitment signal also involves the degree of openness and inclination to share risk with clients in a mutual gain and lost arrangement.

Behaviour Signalling

Clients look for certain behaviour signals which point to contractor's suitability for long-term collaborative relationships in a selection process. Gambetta and Hamill (2005) opined that certain behavioural properties such as honesty, benevolence, a long-term horizon, a pro-social upbringing positively influence the trustworthy guaranty of a person in many trust games including contractor selection for long-term collaborative relationships as is the "trust game" area of interest in this study. In agreement to Gambetta and Hamill (2005) opinion, the across case results of the findings from the organisations investigated (Figure 1) shows that being 'polite', 'honest', 'respectful' and 'realistic' are the significant behavioural signals that indicates contractor's suitability for long-term collaborative relationships in framework contracts. The following quotes from interviews transcript illustrate the display of these signals in a selection process:

> You know when you can tell or confirmed they are lying. When they over promise and are not being realistic. Alpha 1

> Take one example, somebody lied and said he developed A, B, C, and D for a client but when we called the client, he says no, there's no such a thing. This person did not develop that. So automatically we know that he is a liar. Alpha 7

> Mannerly behaviour, I am going to make an example where we had a painting contractor to go on site and quote. He was from another developer, and he was so rude with my guys on site that my site agent called me to tell me that we can let him quote but he must never come back to the site. Alpha 2

Drawing upon the principles of costly signalling (Zahavi, 1975), the behavioural signals are costless to good contractors to display and costly to imitate by a bad contractor for long-term collaborative relationships. Therefore, behavioural signals are a vital indication of the suitability of contractors for selection for in framework contracts given the demands for long-term collaborative relationships.

CONCLUSIONS

The exact observable signals that indicate a contractor's suitability for long-term collaborative relationships were empirically investigated in this study employing signalling theory. Signalling theory helps to explain how one can make a decision relying upon signals, which are perceivable indicators of non-directly observable qualities. The significant signals that indicates contractor's suitability for long-term collaborative relationships evidenced by virtually all the organisations investigated in the study include: Past-performance signals which serves as the best indicator of future performance in regards to long-term collaborative relationship attributes of contractors; commitment signals which not only concerns attendance but also contractor's willingness, participative contributions, standard of tender submissions and top management involvement in the various activities during the selection processes. The other signals are the behaviour signal which comprises of being polite, honest, respectful and realistic. The final verdict will involve taking a cluster of these signals into consideration. These findings are consistent with the predictions of signalling theory, and the presence of these signals will guarantee the rights decisions in selecting suitable contractors for collaboration and long-term relationships.

REFERENCES

Akerlof, G (1970) The market for lemons: Qualitative uncertainty and the market mechanism, *Quarterly Journal of Economics*, 84(3), 488-500.

Ayegba, C and Root, D (2018) *Procurement Tactics for Selecting Suitable Contractors for Collaboration and Long-Term Relationships a Productive Relationship: Balancing Fragmentation and Integration*. ARCOM Compendium of Working Papers 2018. Available from http://www.arcom.ac.uk/-docs/archive/2018-Working-Papers.pdf, 72-81.

Babaeian, J M, Yiu, T W and Wilkinson, S (2016) Assessing contractual relationship quality: Study of judgment trends among construction industry participants, *Journal of Management in Engineering*, 33(**1**), 04016028.

Baiden, B. K and Price, A D (2011 The effect of integration on project delivery team effectiveness, *International Journal of Project Management*, 29, 129-136.

Bulbulia, J and Sosis, R (2011) Signalling theory and the evolution of religious cooperation, *Religion*, 41, 363-388.

Dewberry, C, Hayes, A and Sarhan, S (2018) Behavioural Assessments in Construction Procurement: A Bandwagon of Institutional Waste? *In:* Gorse, C and Neilson, C J (Eds.), *Proceedings 34th Annual ARCOM Conference*, 3-5 September 2018, Queen's University, Belfast, UK. Association of Researchers in Construction Management, 159–168.

Doloi, H (2009) Analysis of pre-qualification criteria in contractor selection and their impacts on project success, *Construction Management and Economics*, 27(**12**), 1245-1263.

Donath, J (2011) *Signals, Cues and Meaning*, Unpublished Manuscript, Available from http://smg.media.mit.edu/papers/Donath/SignalsTruthDesign/SignalsCuesAndMeaning.pdf [Accessed 7/06/2016].

Drover, W, Wood, M S and Corbett, A C (2018) Toward a cognitive view of signalling theory: individual attention and signal set interpretation, *Journal of Management Studies*, 55, 209-231.

Egan, J (1998) *Rethinking Construction*. London: Department of Environment, Transport and Regions.

Frödell, M (2011) Criteria for achieving efficient contractor-supplier relations, *Engineering, Construction and Architectural Managemen*t, 18, 381-393.

Gambetta, D and Hamill, H (2005) *Streetwise: How Taxi Drivers Establish Customer's Trustworthiness*. London: Russell Sage Foundation.

Gambetta, D (2008) Signalling theory and its applications, *In*: *Résumé Des Conférences Du Collège De France (2007-2008)*, L'annuaire du Collège de France Cours et travaux 895-896.

Janney, J J and Folta, T B (2006) Moderating effects of investor experience on the signalling value of private equity placements, *Journal of Business Venturing*, 21, 27-44.

Kamudyariwa, X B, Ayegba, C and Root, D (2018) Implementing effective change in construction through a bottom-up approach towards a better route to enhanced productivity, performance and transformation of construction, *In*: *10th CIDB Postgraduate Research Conference*, Department of Built Environment Central University of Technology, Free State, 445-457.

Khalfan, M M, Maqsood, T and Noor, M A (2014) Relationships among supply chain participants: the case of Australia and Malaysia, *International Journal of Procurement Management*, 7, 376-390.

Kumar, K (1989) *Conducting Key Informant Interviews in Developing Countries*. Washington, DC: Agency for International Development.

Latham, M (1994) *Constructing the Team*. London: Her Majesty's Stationary Office, 54.

Marshall, M N (1996) The key informant technique, *Family Practice* ,13, 92-97.

Mavlanova, T, Benbunan-Fich, R and Lang, G (2016) The role of external and internal signals in E-commerce, *Decision Support Systems*, 87, 59-68.

McNally, W J (1995) *Stock Repurchase Signalling: Theory and Evidence*. PhD thesis, University of Toronto.

Meng, X (2013) Change in UK construction: Moving toward supply chain collaboration, *Journal of Civil Engineering and Management*, 19, 422-432.

Miles, M B, Huberman, A M and Saldaña, J (2014) *Qualitative Data Analysis: A Methods Sourcebook*. Thousand Oaks, CA.: Sage.

Ruparathna, R and Hewage, K (2013) Review of contemporary construction procurement practices, *Journal of Management in Engineering*, 31, 04014038.

Russell, J S, Hancher, D E and Skibniewski, M J (1992) Contractor prequalification data for construction owners, *Construction Management and Economics*, 10(**2**), 117-135.

San Cristóbal, J.R (2011 Contractor selection using multicriteria decision-making methods, *Journal of Construction Engineering and Management*, 138(**6**), 751-758.

Sanchez, M (2012) A collaborative culture, *Od Practitioner*, 44, 7-12.

Saunders, M N K, Lewis, P and Thornhill, A (2012) *Research Methods for Business Students 6th Edition*. Harlow, UK: Pearson Education.

Spence, A M (1973) Job market signalling, *Quarterly Journal of Economics*, 87, 355374.

Spence, M (1974) *Market Signalling: Informational Transfer in Hiring and Related Processes*. Cambridge, MA: Harvard University Press.

Suprapto, M, Bakker, H L, Mooi, H G and Moree, W (2015) Sorting out the essence of owner-contractor collaboration in capital project delivery, *International Journal of Project Management*, 33, 664-683.

Veblen, Thorstein (1899) *The Theory of the Leisure Class*. New York: Macmillan.

Watermeyer, R (2012) Changing the construction procurement culture to improve project outcomes, *In*: *Joint CIB W070, W092 and TG72 International Conference on Facilities Management, Procurement Systems and Public Private Partnerships*, 23-25 January Cape Town, South Africa

Zahavi, A (1975) Mate selection-a selection for a handicap, J*ournal of Theoretical Biology*, 53, 205-214.

DEVELOPING A NEIGHBOURHOOD: HORIZONTAL INTERDEPENDENCIES IN AN INNOVATIVE MULTI-PROJECT CONTEXT

Susanna Hedborg[1] and Tina Karrbom Gustavsson

Real Estate and Construction Management, Kungliga Tekniska Högskolan (KTH), Brinellvägen 8, 114 28 Stockholm, Sweden

Construction projects are increasingly performed in inter-organizational multi-project contexts. Research on innovation in inter-organizational projects has often focused on contractual relationships, for example the vertical and adversarial relationship between client (here called developer) and contractor, or on integrating vertical supply chain relationships. There are, however, other inter-organizational relationships to consider that affect innovation. One example is major urban development initiatives, and other multi-project contexts, where several interdependent construction projects are planned and executed in sequence and parallel in a limited geographical area. This poses challenges on horizontal interdependent actors, between developers that perform their projects simultaneously and, literally, as neighbours. Therefore, the focus of this paper is on horizontal interdependencies in innovative multi-project contexts, specifically between different developers. The horizontal interdependencies are explored through theory on social capital. This focus includes historical and informal relations which develop over time, going beyond the traditional contractual, economical and vertical relationships. Based on empirical data from a longitudinal study of an urban development project including interviews with developers' representatives and observations from meetings, findings indicate that the developers have to collaborate over structures, contracts, logistics and timeframes. Findings also show that developers' collaboration largely depends on their own initiatives over time to create spaces for collaboration.

Keywords: collaboration, multi-project context, social capital, neighbourhood

INTRODUCTION

Activities in the project-based construction industry are structured around collaboration and information sharing (Styhre 2008), both intra- and inter-organizational. In relation to this, there has been a long on-going discussion on the industry's innovativeness (see for example Karrbom Gustavsson 2018, Loosemore 2015). The temporary inter-organizational organizations, characteristic for construction, will affect innovativeness (Manning 2008) due to for example different routines (Levina 2005) and asymmetries of interests and goals (Cabrera and Cabrera 2002). In other words, the inter-organizational relationships, which are central in the project-based construction industry, seem to play an important role in creating an innovative context. Research on the inter-organizational aspects in the construction industry has mainly been studied from a transactional perspective focused on the

[1] susben@kth.se

Hedborg, S and Gustavsson, T K (2019) Developing a Neighbourhood: Horizontal Interdependencies in an Innovative Multi-Project Context *In:* Gorse, C and Neilson, C J (Eds) *Proceedings of the 35th Annual ARCOM Conference,* 2-4 September 2019, Leeds, UK, Association of Researchers in Construction Management, 304-313.

contractual relationships. The vertical and adversarial relationship between client and contractor when studying project partnering (see for example Eriksson 2015) and the integration of vertical relationships between client, consultant, contractor and sub-contractor in supply chain management (see for example Vrijhoef and Koskela 2000) are two examples.

A consequence of the on-going urbanization, construction projects are more likely to be performed in multi-project contexts. Performing projects in a multi-project context raises a number of issues; project interdependencies, priority setting and resource re-allocation, competition between projects and short problem solving (Engwall and Jerbrant 2003). Engwall and Jerbrant (2003) suggested that resource allocation needed most attention in intra-organizational multi-project contexts, when the context becomes inter-organizational other issues might become more relevant. One example of such inter-organizational multi-project context is urban development projects where different developers build side by side. Hence, an innovative urban development context will involve and affect many different organizations and actors (Smith 2016), creating interdependencies between construction projects. When exploring innovative multi-project contexts other relationships than the contractual and vertical stands out, namely the horizontal relationships between parallel and sequential projects in the same context, performed by different developers. In urban development, these horizontal relationships often start of as informal and are generally not self-chosen. Instead, the initiator of the urban development project, e.g. a municipality, has decided which developer should build what and where. These prerequisites create horizontal interdependencies between the different developers.

Clients (from here on called developers) are identified as a bridging actor to serve the collaboration for innovation (Kulatunga *et al.,* 2011). The inter-organizational network becomes important when innovation moves from a single project to a multi-project context (Bygballe and Ingemansson 2014). Such innovative context often requires tight communication (Eriksson and Szentes 2017) and negotiation of boundaries (Karrbom Gustavsson 2018). In multi-project context a tight communication between the different developers is therefore important to bridge the divide between the different organizations and projects. In this paper we will focus on the horizontal interdependencies between developers performing construction projects in parallel next to each other within a limited area. In other words, as neighbours, being immediately adjoining or relatively near one another, in what is planned to be an innovative and sustainable city.

One way to study informal relationships within communities is from the lens of social capital, describing the importance of networks of relationships as a source of competitive advantage (Bourdieu 1985). Social capital, contrary to economic and human capital, relies on the structure of relationships to other individuals or corporate actor (Portes 1998). Social capital in the construction industry has been scarcely research, where the few studies have focused on social capital intra-organizationally within a certain workforce (Bresnen *et al.,* 2005, Styhre 2008) or in single projects (Di Vincenzo and Mascia 2012). As Subramaniam and Youndt point out, social capital comes from "the interactions among individuals and their networks of interrelationships" (2005: 451). To a large extent the project-based nature and often multi-project context of the construction industry creates and rely on inter-organizational relationships, therefore the social capital in those relationships becomes important to understand.

In the case presented here a municipality has created horizontal interdependencies between appointed developers due to shared prerequisites. With a starting point in theories on communities, social capital will help explain these horizontal interdependencies between the neighbouring developers in the innovative multi-project context. Where the purpose is to increase the knowledge of horizontal interdependencies in innovative multi-project contexts by exploring what social capital have been built up between the developers in order to handle these interdependencies. Based on this, the research questions are; what horizontal interdependencies have the developers handled when performing construction projects in an innovative multi-project context and what social capital have the developers built up in order to handle the horizontal interdependencies? These questions have been explored by combining theory on social capital with a longitudinal study of three clients performing construction projects in parallel within the same urban development project.

THEORETICAL FRAMEWORK

Social Capital and Neighbours

The term social capital evolved from community studies on networks developing over time in order for individuals and groups to survive and function in a neighbourhood (Nahapiet and Ghoshal 1998). Over the past decades many definitions and understandings of social capital have been developed, they all share the view that the networks in which individuals and groups are embedded in are important for competitive advantage (Bresnen *et al.,* 2005). To the contrary of other types of capital, e.g. human or physical, social capital exists in the structure of relationships between actors, rather than within individuals or in tangible objects (Coleman 1988, Portes 1998). Social capital is not owned by one actor, it is jointly held by the parties included in the relationship (Burt 1997). Due to the focus on relationships, social capital both builds on and creates collaboration, trust and collective actions (Nahapiet and Ghoshal 1998). Coleman (1988) suggests that a group can accomplish more if extensive trust exists within the group. Another aspect of social capital is the creation of norms, where the norm to act for the collective rather than in self-interest is especially strong (Coleman 1988).

Social capital is in this paper seen as "features of social organization such as networks, norms, and social trust that facilitate coordination and cooperation for mutual benefit" (Putnam 1995: 67). In more detail the paper will apply Nahapiet and Ghosal (1998) division between structural, relational and cognitive dimension of social capital, which also Bresnen *et al.,* (2005) used when exploring social capital in the construction industry. The structural dimension, firstly, is the pattern of the network of actors, who can reach who and how. This dimension describes the existence or lack of ties between actors, in terms like hierarchy, density and connectivity. Second, the relational dimension is what kind of relationships individuals or groups have developed through interactions. The focus is put on relations that influence behaviour and create assets such as identification, norms, trust and expectations. Lastly, the cognitive dimension describes the individuals and groups perceived value of being a part of the network. It describes the resources from which the actors receive representations, interpretations and meaning.

Earlier research has concluded that organizations can increase their innovative context by leveraging social capital (Nahapiet and Ghoshal 1998), and that social capital is being mobilized in innovative communities (Adler and Kwon 2002). Moreover, it has

been suggested that a focus on social and organizational aspects of knowledge creation and sharing is important for understanding innovation processes (Brown and Duguid 2001). As Styrhe (2008) points out, there has been a limited amount of studies on social capital focusing on the construction industry. The project-based context affects innovation processes and relationships, by being temporary and inter-organizational, why the social capital in this context is interesting to explore further (Bresnen *et al.,* 2005). It is suggested that it is more difficult to sustain social capital in project-based context as groups and networks change continuously (Bresnen *et al.,* 2005) but thereby social capital might also be even more relevant (Hansen 2002).

RESEARCH APPROACH

The empirical findings are based on a longitudinal study of an urban development project in Stockholm, Sweden. More specifically, three developers, performing multi-family housing projects, have been followed during the course of their projects, from design and procurement to completion and hand over, for a total of three years. A longitudinal study has gained insight into the process where social capital has developed over time. A qualitative approach has been used in order to ensure rich explanations when studying actors' role from practice (Silverman 2013). The empirical material has been gathered from several sources to create a context dependent understanding of the on-going case (Flyvbjerg 2006). These include an early workshop with the developers' project managers, six observed planning meetings between the municipality and the developers' project managers, and interviews with three developers' project managers in the early phases as well as follow-up interviews with two of the developers during production and with all three developers again during completion (developer 1, 6 and 8). In addition to the eight interviews with developers, context dependent information was gathered from other types of meetings, informal discussions and over forty interviews with developers, contractors, operators and representatives from the municipality.

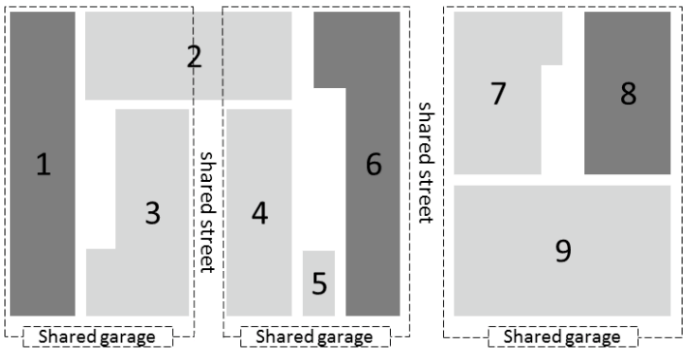


Figure 1: Overview of the nine developers, including shared assets

The context of the urban development in which the developers carry out their projects is characterised by a limited construction area where nine different developers build side by side in two different blocks where each block shares streets, backyards and garages, see figure 1 for illustration. The developers differ in that some build multi-family housing to sell as cooperatives other build rental housing planning to manage the buildings long term. The three developers (Developer 1, 6, 8) who have been followed are spread out in these two blocks in order to capture different issues of building in this context. The chosen clients are also different in that Developer 8 is responsible for the facility management of the finished multi-family housing building, while Developers 1 and 6 leave this to the future residents. Moreover, a high level of

sustainability requirements was established by the municipality, leading to an innovative context, both in terms of innovation initiative from the municipality and the need to carry out innovative solutions for the developers. The gathering of empirical material has focused on how this innovative multi-project context has affected the developers, in terms of prerequisites, interdependencies between projects, and their procurement of contractors. From this social capital, as defined above, has been used as analytical lens to understand the horizontal interdependencies in the parallel construction projects performed by different developers in the same innovative multi-project context. In more detail, the empirical findings were analysed by using the three dimensions of social capital suggested by Nahapiet and Ghosal (1998), structural, relational and cognitive.

FINDINGS

Structural Dimension Between the Projects

As highlighted in the introduction, the multi-project context of an urban development project consists of a large number of both vertical and horizontal structural ties. The network of relationships in focus here is that between the developers in parallel projects, and in extension their contractors and the municipality. The relationship between the developers is informal at the starting point of the projects, where the project managers refer to the municipality as a coordinator between the developers. The project manager at Developer 8 describes it as an "organized chaos" when discussing the required collaboration between the projects. All interviewed developers highlighted the fact that this is not a project that they can perform without cooperation, especially as they have close-by neighbours performing parallel projects. The project manager at Developer 1 explains that "this is not a field where you can just set up your own stuff and start work".

All developers have some neighbours that are closer and with whom they share for example backyard and garage, those ties are naturally more important. As project manager at Developer 8 puts it, after having described their relationship with their closest neighbour; "we are also neighbours with others, but not structurally". The project manager at Developer 6 suggests that the site manager at their appointed contractor should handle the collaboration between the projects. Even though some developers are closer than others they are all in the same context, in the sense that they have the same responsibilities towards the municipality, exist in the same overall structure. For example, they have the same high sustainability requirements that they have to meet, they all have to use the construction logistics centre for all on-site coordination, and they have to meet the coordinated time tables. The municipality arranges a meeting every month with all developers where they inform of the latest activities and encouraged the developers to share their progress. From the meeting observations it is visible that these meetings are mainly used by the municipality to share information whereas the developers are rather quiet. However, during small talk before and after the meetings the developers interact and discuss their projects informally.

Relational Dimension Developed Over Time

From the structural ties, as described above, some patterns of relationships have developed over time during project execution. Apart from the formal meetings arranged by the municipality, the developers' project managers describe meetings initiated by themselves, mainly between the closest neighbours, with whom they share

street, backyard or garage. The developers have initiated different "work groups" where they have overlapping interests. As exemplified by project manager at Developer 8, they share backyard with four other developers with whom they have started a meeting forum. They also share a small street with two other developers; during the production phase they realized that this affected their projects a lot and thereby started a meeting forum to discuss joint issues. Moreover, project manager at Developer 6 highlights that apart from meetings "it's starting to pop-up contracts between developers, so we won't be able to let each other down", and continue reflecting that "it's good, I guess, to have something on paper even though you want to have faith in one another". One example of this is found at Developer 1, where they have created a joint sub-project together with their two closest neighbours in order to carry out their common garage and backyard. They have appointed one external project manager consultant to run the project, and they meet every other week to coordinate in what they call a "developer forum".

Developer 6 has another example of how they have developed formal relationships to their closest neighbour. When procuring their contractors, they realized that they would need an extensive amount of coordination as they shared basement with a garage. To handle this they decided to procure the same contractor, their project manager says "we found one contractor, it was not the cheapest for either one of us, but they felt stable…in order to minimize the friction". During the last interview, at project completion, the project manager describes several issues with sharing one contractor. They had to delay their time plan to account for delayed deliveries in their neighbour's project. Moreover, they had planned to share site office and site personnel to ensure coordination, in the end they had to set up two separate site offices due to project overload for the site personnel. When asked if the project manager would have been procured in the same way in hindsight, he was doubtful and said that a conventional procurement strategy might have worked better. Their developed relationship changed over the projects process.

When reflecting on the municipality's role in bringing the developers together the project manager at Developer 1 sum up "the people at the municipality are great at the informal interaction, they are willing to help and solve issues. But at a formal level, at a contract level and where different responsibilities lie, for example crane coordination, there is room for improvement so to say." The crane coordination is a much-discussed issue both on a formal and informal level. From meeting observation spanning over a year, this issue is discussed over and over again. The municipality try to encourage the developers to handle the coordination or even to collaborate by sharing cranes. Meanwhile the developers sat back and awaited orders on how to deal with the large number of cranes within a relatively small area. At a meeting after production had started, but the issue had not been solved yet, one developer jokingly says, "it looks like we don't have to put up a crane we can just use everyone else's". A participant from the municipality sighs and says "Yes, that arrangement would have been the preferred one from the start". The project manager at Developer 1 reflects over the issue with crane coordination that" we could just go to the other developers, or contractors, and say please don't place your crane there… but for some reason we don't".

Cognitive Perception of the Relationships

An overall view is that the developers seem to have both positive and negative perception of the ties and relationships with their neighbours. As illustrated above, on

one hand they feel that there is a lot of coordination happening, but on the other hand they seem to appreciate their neighbours' experiences. Developer 1's project manager explains happily that “our neighbours are two very skilled developers”. Another example of positive aspects from having neighbours is highlighted by the project manager at Developer 6, describing that they discussed the construction logistics centre with a developer who had built in the area before, and therefore had used the centre, in order to get their experiences of dos and don'ts. However, it seems that the developers do not continuously share their experiences. Project manager at Developer 8 says that they had difficulties to deliver on the high energy requirements, but in the end found a solution using the waste water for heating. He said that all developers faced this issue but when asked if he had shared their solution with the other, he said: “no, not really”. Here they did not use their developed relationships.

Apart from the horizontal relationship between developers, the three developers' project managers reflect a lot around their relationship with their appointed contractors. All of them perceived these relationships as being extra important in projects with this high level of complexity, in terms of sustainability and innovative requirements. When describing their procurement strategy, the project manager at Developer 8 says; “the industry has shown a large interest to be involved early”. Meanwhile, the project manager at Developer 1 reflects over that they are “very dependent on being perceived as an attractive client for the contractors”. In other words, the developers cannot just approach the contractors that they perceive as knowledgeable and trustworthy, they must take their own appearance into account in order to attract contractors. In the same spirit, the developers reflect over the importance of creating good prerequisites for their end customers, the residents. Developer 6, who plans to have sold their apartments at project completion, says that they perceive a difference between the developers. Developers with a long-time horizon (e.g. public rental organizations) seem to value their relationships more. On the other hand, developers that sell their apartments in the form of a cooperative tend to be more focused on on-time and on-budget, whilst at the same time creating high-end apartments for their buyers. The project manager at Developer 1 says he sees the other developers as “colleagues” but at the same time realize that they compete over the same end-customers, selling their finished apartments at the same time.

DISCUSSION

Social Capital Between the Developers

By analysing the empirical findings from the three dimensions of social capital, structural, relational and cognitive (Nahapiet and Ghoshal 1998), it becomes apparent that the developers act as neighbours. The findings also indicate that they do not use their potential social capital to its full extent. To compare developers building next to each other to community neighbours seems effective as it can point towards what relationships developers actually have and build over time, but also that how they interact affects their project performance. Being a developer in an urban development project you know you will have neighbours, but you will not know who before your project starts. In a Swedish context, this is in most cases decided by a municipality. The findings show that the neighbours affect each other to a large extent, sharing structure, creating contracts and coordinating time plans and logistics. Compared to the much-discussed vertical relationships that developers create with contractors, suppliers and consultants (Eriksson 2015, Vrijhoef and Koskela 2000), in these horizontal interdependencies they cannot ask for and decide on the options best suited

for their own project. They have to trust the municipality to choose appropriate neighbours to collaborate with and informally develop required relationships. This case study has shown that the developers have approached this issue with different success, some initiative have been fruitful whilst others have further complicated their projects. What can be concluded from this is the importance of taking the horizontal interdependencies into account and to build relationships from these over the project time in order to be able to carry out the construction projects.

Horizontal Interdependencies in the Multi-Project Context

The municipality aimed for the area to be innovative in order to create sustainable urban development, both by putting in place strict requirements on the developers and by hoping that they would take own initiatives. In line with previous findings (Bygballe and Ingemansson 2014, Cabrera and Cabrera 2002, Levina 2005) an innovative inter-organizational context seems to be difficult to come by. In the few examples where developers describe that they have used somewhat innovative solutions it has been primarily to benefit their own project with no formal experience sharing has been identified. The developers' own innovative solutions are not spread beyond their single project boundaries (Karrbom Gustavsson 2018). The findings also show that when the developers mobilize their social capital to handle the innovative context (Adler and Kwon 2002) their effort does not hold up all the way. As Bresnen *et al.,* (2005) point out this can be due to projects short timeframe as relationships take time to build up.

While Engwall and Jerbrant (2003) focus on resource allocation as a main issue for intra-organizational multi-project contexts the focus here has been on the interdependencies between parallel projects. Interdependencies between projects are regarded as difficult; especially if the projects are close neighbours and share some tangible structure such as a garage or backyard. To handle this, the developers have, during production, created meeting forums and contracts to handle both the production and the long-term facility. Two other interdependencies that affect the production for the developers have been identified, namely; logistic issues regarding shared infrastructure and that they have to coordinate their time plans as they build close to each other. All in all, the findings have identified that the developers have to coordinate over structures, contracts, logistics and timeframes.

Another issue with interdependencies between parallel construction projected performed by different developers is the fact they might be competitors over the same end-customers i.e. those who will buy or rent their apartments. Therefore, the developers have a balancing act in that they must collaborate in order to carry out their project, but at the same time they collaborate with their competitors. Compare with Coleman's (1988) findings that the norm to act for the collective rather than in self-interest is strong. In line with this, the developers did not express such difficulties in collaborating with competitors. One reason for this could be their varied business models as some are private developers who will sell the buildings to cooperatives, handling the facility management. In the other end of the spectra are the public developers responsible for the facility management and renting out their apartments on the controlled rental market. Another issue regarding time frame is that projects often have short time frames, which affect collaboration as relationships and social capital take time to build (Hansen 2002). Even though construction projects take long time to complete, participants often have a single project focus believing they will not work with the same people again.

CONCLUSIONS

The purpose has been to increase the knowledge of horizontal interdependencies in innovative multi-project contexts by exploring what social capital has been built up between the developers in order to handle these interdependencies. From a longitudinal study of three developers performing construction projects in an urban development project, the findings show that there exist several horizontal interdependencies between the parallel projects. When different developers perform projects as neighbours, i.e. build close-by in a limited area, they become interdependent structurally, contractually, logistically and time wise. These interdependencies are embedded in the multi-project context and affect the developers both during design and production, as well as in the long-term facility management. To handle these interdependencies the developers, have to collaborate. The findings show that they do, to some extent, build up and use social capital in order to create inter-organizational (inter-project) relationships.

With the on-going urbanization in mind, the findings contribute to the construction management literature by highlighting the importance to take horizontal interdependencies into account when exploring collaboration and innovation between inter-organizational actors and projects. Rather than to just focus on formal, e.g. contractual, relationships horizontal interdependencies is a main issue in construction projects in multi-project contexts. The findings also contribute to multi-project management literature by presenting a novel empirical multi-project context. Implication for construction management, both developers and governmental actors, to be drawn from this is that when performing parallel and sequential construction projects in multi-project contexts the horizontal interdependencies must be planned for and resources allocated to handle the required collaboration. The findings should be viewed as tentative where comparative studies from other multi-project contexts are suggested and also to extend the knowledge of how parallel developers actually handle the interdependencies from a practice perspective.

REFERENCES

Adler, P S and Kwon, S W (2002) Social capital: Prospects for a new concept, *Academy of Management Review*, 27(**1**), 17-40.

Bourdieu, P (1985) The social space and the genesis of groups, *Social Science Information*, 24(**2**), 195-220.

Bresnen, M, Edelman, L, Newell, S, Scarbrough, H and Swan, J (2005) Exploring social capital in the construction firm, *Building Research and Information*, 33(**3**), 235-244.

Brown, J S and Duguid, P (2001) Knowledge and organization: A social-practice perspective, *Organization Science*, 12(**2**), 198-213.

Burt, R S (1997) The contingent value of social capital, *Administrative Science Quarterly*, 42(**2**), 339-365.

Bygballe, L E and Ingemansson, M (2014) The logic of innovation in construction Industrial, *Marketing Management*, 43(**3**), 512-524.

Cabrera, A and Cabrera, E F (2002) Knowledge-Sharing Dilemmas, *Organization Studies*, 23(**5**), 687-710.

Coleman, J S (1988) Social capital in the creation of human capital, *American Journal of Sociology*, 94, S95-S120.

Di Vincenzo, F and Mascia, D (2012) Social capital in project-based organizations: Its role, structure and impact on project performance, *International Journal of Project Management,* 30(**1**), 5-14.

Engwall, M and Jerbrant, A (2003) The resource allocation syndrome: The prime challenge of multi- project management? *International Journal of Project Management*, 6(**21**), 403-409.

Eriksson, P E (2015) Partnering in engineering projects: Four dimensions of supply chain integration, *Journal of Purchasing and Supply Management*, 21(**1**), 38-50.

Eriksson, P E and Szentes, H (2017) Managing the tensions between exploration and exploitation in large construction projects, *Construction Innovation*, 17(**4**), 492-510.

Flyvbjerg, B (2006) Five misunderstandings about case-study research, *Qualitative Inquiry*, 12(**2**), 219-245.

Hansen, M T (2002) Knowledge networks: Explaining effective knowledge sharing in multiunit companies, *Organization Science*, 13(**3**), 232-248.

Karrbom Gustavsson, T (2018) Liminal roles in construction project practice: exploring change through the roles of partnering manager, building logistic specialist and BIM coordinator, *Construction Management and Economics*, 36(**11**), 599-610.

Kulatunga, K, Kulatunga, U, Amaratunga, D and Haigh, R (2011) Client's championing characteristics that promote construction innovation, *Construction Innovation*, 11(**4**), 380-398.

Levina, N (2005) Collaborating on multiparty information systems development projects: A collective reflection-in-action view, *Information Systems Research*, 16(**2**), 109-130.

Loosemore, M (2015) Construction innovation: Fifth generation perspective, *Journal of Management in Engineering*, 31(**6**), 04015012.

Nahapiet, J and Ghoshal, S (1998) Social capital, intellectual capital and the organizational advantage, *Academy of Management Review*, 23(**2**), 242-266.

Portes, A (1998) Social capital: Its origins and applications in modern sociology, *Annual Review of Sociology*, 24(**1**), 1-24.

Putnam, R D (1995) Bowling alone: America's declining social capital, *Journal of Democracy*, 6(**1**), 65-78.

Silverman, D (2013) *Doing Qualitative Research: A Practical Handbook 4th Edition*. London: Sage Publications.

Smith, P (2016) Boundary emergence in inter-organizational innovation the influence of strategizing, identification and sensemaking, *European Journal of Innovation Management*, 19(**1**), 47-71.

Styhre, A (2008) The role of social capital in knowledge sharing: the case of a specialist rock construction company, *Construction Management and Economics*, 26(**9**), 941-951.

Subramaniam, M and Youndt, M A (2005) The influence of intellectual capital on the types of innovative capabilities, *Academy of Management Journal*, 48(**3**), 450-463.

Vrijhoef, R and Koskela, L (2000) The four roles of supply chain management in construction, *European Journal of Purchasing and Supply Management*, 6(**3**), 169-178.

EARLY CONTRACTOR INVOLVEMENT IN THE CONSTRUCTION INDUSTRY: A PRELIMINARY LITERATURE REVIEW

Anna af Hällström[1] and Petra Bosch-Sijtsema

Technology Management and Economics, Chalmers University of Technology, Chalmersplatsen 4, Gothenburg, Sweden

The Early Contractor Involvement (ECI) concept focuses on increasing efficiency in the construction process by involving the contractor in the design phase and has increased in popularity in recent years. The concept is not new, and the main body of literature applies a relatively unified understanding of the concept. There are, however, differences in the literature on how ECI is applied due to contextual differences. The goal of this paper is to provide a preliminary schematic analysis of current ECI literature and examine the current ECI research. ECI is placed in the wider umbrella framework of relationship contracting, together with alliancing and partnering. The similarities and differences will be briefly touched upon. The literature review is based on a database query in Scopus and Web of Science. A total of 4 648 articles were identified initially, focusing on key words of 'early contractor involvement' or 'ECI'. The search was further refined by adding the key-words 'construction' an 'building', forming a core list of 332 articles. Further refining by comparing abstracts and key-words, as well as the definition of 'ECI' in the text resulted in a curated list of 27 articles. The articles were then compared on type, method, theory, contribution and context/country. The review reveals a rather unified definition of ECI, but contractor involvement early in the design can be found in multiple concepts related to collaborative management models. The focus of the literature is also mainly on the contractual phase and less attention is given to project governance and execution. The literature focuses on the contractual aspects and incentive structures of ECI, while less focus is on how ECI is organized in the project, the division of responsibility and sharing of amongst the partners. Furthermore, there is a difference in how the concept of ECI is applied in different countries. The review also finds that multiple types of methods are applied in ECI studies but that few studies apply a theoretical lens or endeavour to contribute to theory. The article discusses the literature as well as possible future research.

Keywords: ECI, contracting, literature review, procurement, project management

INTRODUCTION

Large and complex infrastructure projects suffer from low productivity levels and adversarial relationships (Rahman and Kumaraswamy 2004, Rahman and Alhassan 2012, Volker *et al.,* 2018) as well as unpredictable outcomes (Chen *et al.,* 2018). As research regarding the construction industry has focused on reducing the aforementioned challenges, a multitude of different project management solutions have developed in both procurement as well as governance. There has recently been a

[1] anna.af.hallstrom@gmail.com

af Hällström, A and Bosch-Sijtsema, P (2019) Early Contractor Involvement in the Construction Industry: A Preliminary Literature Review *In:* Gorse, C and Neilson, C J (Eds) *Proceedings of the 35th Annual ARCOM Conference,* 2-4 September 2019, Leeds, UK, Association of Researchers in Construction Management, 314-323.

heightened awareness of the importance of chosen management and contractual forms and the use of collaboration-based frameworks and tools to develop the relationships between client and contractor has grown (Chen *et al.,* 2018, Bygballe, Jahre and Swärd 2010, Hastie, Sutrisna and Egbu 2017, Mosey 2009). Eadie and Graham (2014) note in this respect that the early involvement of contractors improves project performance. As complex infrastructure projects are major undertakings, both in terms of scope and scale, and the involved parties have different drivers (Rahman and Kumaraswamy 2004), it becomes relevant to help adopting a collaborative perspective in the early design stages: it is in the project's starting phase that the specialist's input has the biggest influence on the project outcomes, such as timetable and cost structure, as well as in improving risk management and the collaboration between client and contractor (Laryea and Watermeyer 2016). This has resulted in a heightened focus on collaborative procurement forms emphasizing this early stage of the process. These approaches to collaboration and co-operation in construction can be gathered under the term of 'relational contracting' or 'relationship contracting' (Rahman and Kumaraswamy 2004). The concepts are applied to both the procurement phase (Chen *et al.,* 2018) as well as execution and governance of the project. The collaborative procurement models are used to stimulate collaboration between stakeholders and can be found in such collaborative models as alliances, partnering, integrated project delivery, and early contractor involvement. The literature focuses increasingly on a combination of collaborative procurement models (e.g., Chen *et al.,* 2018), which seem to overlap to some extent. This article focuses primarily on the involvement of contractors early on in the design process but refers to some extent to other collaborative models as well.

The Early Contractor Involvement (ECI) concept has become more popular in recent years and focuses on increasing efficiency in the construction process by involving the contractor early in the design phase (Eadie and Graham 2014, Laryea and Watermeyer 2016, Mosey 2009, Rahman and Alhassan 2012). The concept is not new, and the main body of literature applies a relatively unified theoretical understanding of the concept. There are however differences in how ECI is applied and organized which may vary by country and local context (Laryea and Watermeyer 2016). In Sweden, a number of major and complex projects related to transport infrastructure and construction are nowadays undertaken with a contractual form based on Early Contractor Involvement (ECI). To better understand the concept of ECI and its applicability for the Swedish context, there is thus a need to look at how ECI is defined and studied in the current literature.

The goal of this paper is to analyze the ECI literature and examine gaps and future research areas in the literature concerning ECI. ECI is placed under the wider umbrella framework of relationship contracting, together with partnering and alliancing. The similarities and differences of the models are briefly touched upon, before a deeper analysis of the literature pertinent to ECI is performed and findings are discussed.

METHOD

This paper is based on findings from what Grant and Booth (2009) call a scoping review. Such a review "provides a preliminary assessment of the potential size and scope of available research literature. It aims to identify the nature and extent of research evidence" (Grant and Booth 2009: 101). One of the objectives of a literature review is to identify methodological concepts commonly used in relevant research

(Hart 2014). This paper performs a preliminary examination of how literature on ECI defines the concept and what methods are commonly used in current research. Below we present the methodology for (a) choosing literature sources and (b) describing and classifying key ideas and concepts, as recommended by Grant and Booth (2009).

A total of 4648 articles were identified in the first search, focusing on all articles containing the key word 'early contractor involvement' or 'ECI' in the Scopus and Web of Science databases. Other formulations, such as 'collaboration models in construction' were considered but were rejected due to the focus on ECI as a distinct concept. There was no time limit set in the search, other than those imposed by the databases. The search was further refined by combining the original query with 'construction' and 'building', forming a core list of 332 articles. This list was curated by limiting the search to first the areas of 'engineering' and 'business' (163 articles) and further by limiting the journals to those pertaining to the construction industry as well as project management and procurement (96). The resulting database was checked for duplicates as well as book reviews, editor's notes, etc., resulting in a list of 93 articles. The list was further refined by examining the articles for the following factors:

- - The abbreviation 'ECI' was used in another context than our definition
- - The words 'construction' or 'building' were used in another context than related to early contractor involvement in the construction industry

This resulted in a curated list of 27 articles to be used as the basis for our literature review. These articles were classified according to publication: (1) peer-reviewed journals, (Scopus/WOS) in construction engineering and management and project management, and (2) conference proceedings, such as proceedings from ARCOM. Adapting the method chosen by Bygballe *et al.,* (2010), the study was based only on the result provided by the chosen search parameters and the refining selection process. We have therefore excluded other definitions and concepts of relational contracting, such as 'partnering' and 'alliances' from the search. The concepts are briefly discussed later on to help frame the main discussion on ECI.

Early Inclusion of Contractors in Construction

The outcomes of infrastructure projects are hard to predict (Chen *et al.,* 2018). Changes in the construction industry and adaptation of new procurement forms is slow. A major reason seems to be the slow decision-making process and client response, but literature also discusses the slow pace of change in the entire industry (Bourn 2007, Eriksson 2008, Jones 2014, MohammadHasanzadeh, Hosseinalipour and Hafezi 2014, Mosey 2009). There is a globally increasing interest regarding collaborative approaches to infrastructure procurement. This is mainly due to their potential to improve project performance in relation to more traditional approaches (Chen *et al.,* 2018), as well as the benefits of long-term relationships between clients, contractors, and consultants which are mainly due to shared experience and knowledge (Naoum 2003). Furthermore, the early inclusion of contractors in construction projects improve the performance of the project, but only if the parties involved commit to the procurement form (Eadie and Graham, 2014). ECI is a subspecies of the field of relationship contracting (Rahman and Kumaraswamy 2004) and will thus be framed with this topic in mind. Below a number of theoretical constructs are discussed except for integrated project delivery (IPD). The reason for not including the IPD model is the lesser extent this model in Europe and the more

integrated collaborative models as discussed in literature are often a combination of the collaborative constructs discussed below (see Chen *et al.,* 2018).

Relationship contracting has been defined as "a process to establish and manage the relationships between the parties that aims to: remove barriers; encourage maximum contribution; and allow all parties to achieve success" (Australian Constructors Association, 1999: 4). This approach can also be defined as relational project delivery arrangements (RPDAs) (Lahdenperä, 2012) The approach is focused on project completion within schedule and budget and is based on strong interpersonal and - organisational relationships. This requires a certain amount of trust as well as open communication and information sharing. The benefits of shared experience and knowledge, born from long-term relationships between clients, contractors, and consultants (Naoum 2003), are a key source of trust.

Trust is the cornerstone of cooperation and collaboration (Jelodar, Yiu and Wilkinson, 2016) and trusting actors in a long-term relationship have the possibility to adapt to each other. Adaptation contributes to improved efficiency and effectiveness in the network created by the actors, enhancing project performance. Relationship contracting also encapsulates the notion that 'lowest cost' isn't the only factor a customer should look at while deciding on which contractor to select for a construction project (Naoum 2003). One of the contractor's benefits of considering not only the final cost of a project, but also other factors like time, operating costs, impact on environment, and site safety, is that the process helps analyse, define, and prioritize the client's needs and objectives (Naoum 2003). Two of the most common models in the European RPDAs are project alliancing and partnering. 'Alliancing' is traditionally defined as an agreement "to work co-operatively and to share risk and reward, measured against key performance indicators" (Gunn 2002: 3).

An alliance contract involves a mutual view on the risks and rewards in a project, as well as a shared responsibility for the involved partners and an agreed method to solve disagreements (Gunn 2002). Characteristics of an alliance organisation are (1) a common contract, which defines the project organisation; (2) a common organisation, of which all parties of the alliance team are a member; and (3) a common sharing of risks (Lahdenperä 2009). Concerning 'partnering', there is no generally accepted concept of 'partnering', even though much of the industry refers to and uses the Construction Industry Institute's definition (Bygballe, Jahre and Swärd 2010). Partnering indicates a commitment on both close collaboration as well as aligning the internal goals of the participating organizations with each other (Aarseth *et al.,* 2012). According to Aarseth *et al.,* (2012) and Naoum (2003), the definition of a partnering relationship is fourfold: (1) the parties have agreed intentions for the cooperation, (2) there is a level of trust between the organizations participating in the partnering arrangement, (3) the parties have agreed on processes to solve problems and disputes, and (4) the cooperation includes a process for continuous improvement. Bygballe *et al.,* (2010) define three key dimensions of partnering relationships, related to the duration of the relationship and its partners, as well as how the relationship develops. The discussion on which effect the concept of partnering has on the construction industry in particular is still ongoing and there is no unified way of defining partnering (Bygballe, Jahre and Swärd 2010). It is difficult to compare these concepts, as well as other RPDAs, as their definitions are fluent and the usage of RPDA is context specific (Lahdenperä, 2012).

Early Contractor Involvement

Early contractor involvement (ECI) is "a partnering approach in which the contractor is appointed at an early stage of project development to assist in planning, assessing buildability and cost estimating" (Nichols 2007: 31). An important part of ECI is the relationship between the contractor and the client or the designer allowing the contractor to be involved in the project from an early stage of design and contribute their construction knowledge and experience to a design (Eadie and Graham 2014, Laryea and Watermeyer 2016, Walker and Lloyd-Walker 2012). There are also some findings indicating that ECI is a more reliable way of achieving the desired outcomes than more traditional methods, such as design and build or public finance partnership/public private partnership (Eadie and Graham 2014). Walker and Lloyd-Walker (2012) state that ECI can take place in all construction phases and can be implemented by a diverse set of procurement forms which can include e.g., partnering and alliancing.

ECI in Literature

The most interesting find was the approach taken on theory building. Almost all analysed articles focus on case studies and the empirical data found therein, while few present a theoretical foundation for their methods or discuss possible contributions to either building or verifying theory.

Most of the articles focused on ECI base their work on empirical studies and qualitative methodologies. Methods identified included case analysis, interviews, document analysis, model comparison, and observation, but also an instance of quantitative method in the case of a questionnaire being utilised. Case analysis was the most frequently used method, employed in 20 out of 27 articles, followed by interviews, which were utilized in almost 50 % of the articles. Document analysis was also quite popular, as 30 % of analysed articles employed some sort of document analysis or review. A more quantitative approach is applied in four papers in the form of surveys or a questionnaire, but only one article stated outright that they used quantitative methods, employing a survey distributed to 100 participants.

The majority of papers were collaborations by two or three authors, which indicates a lack of structured research in the area. A larger number of authors would indicate the existence of research groups, which in turn would indicate a continuous interest in the field. Most authors also only participated in one or two papers in this field, indicating a lack of continuous personal interest. Only five authors worked on more than 3 papers, which means that almost 93 % of authors in the field only contributed to one or two papers.

As literature on ECI is mainly based on case studies and draw from the same source materials and references, the themes found were therefore similar throughout the literature and centred on the prerequisites for and implementation of ECI, although some geographical differences could be noted.

The Approach to ECI

One of the main advantages found in the ECI literature is the benefits it seems to offer in terms of project management. Nichols (2007) defines both benefits and detriments for ECI and many articles refer to Nichols in this respect. On the positive side, ECI enables the contractor to give their input at the most beneficial time; it has the potential to reduce preparation time for projects by 30-40%; provides the client with a better understanding of the project's cost structure; provides greater cost certainty;

increases innovation; and enables a spirit of teamwork (Nichols, 2007). Eadie and Graham (2014) build upon this by further identifying two benefits of ECI in construction procurement: the contracts become less adversarial, and aid in project sustainability. "[T]his is achieved through ensuring design criteria, strategic fit and briefing documentation delivers despite the paucity of information at the early project stages […] the improvements are the result of innovative solutions, better project control, and savings on time and money" (Eadie and Graham 2014: 662). The authors further show that the decision-making process is a common benefit, and that there is a better awareness and understanding of the project risks with ECI than with traditional methods of contracting and procurement (Eadie and Graham 2014).

Table 1: Methods used in the reviewed literature

Methods applied	No. of articles	%
Case study	20	74
Document analysis	8	29
Interview	13	48
Model comparison	3	18
Observation	1	3
Survey or questionnaire	4	14

The main potential drawbacks related to ECI are mostly tied to the novelty of the approach - as few actors are used to working with ECI, there is a learning curve to take into account; the discrepancy between cultures of the partners which is a hindrance for a successful design and build-process as well as an ECI process; the incentives used haven't fully met the needs of either client or contractor; and the lack of team culture when client and/or contractor haven't committed to the ECI approach (Eadie and Graham 2014, Nichols 2007, Pheng, Gao and Lin 2015). Eadie and Graham (2014) also caution against using ECI as a model for all projects, as projects with a short duration, low complexity, or high specification might need more control and management by the client. In such projects, the ECI model may make matters unnecessarily complex and is thus best suited for projects with high ratios of complexity, value, and risk.

As there is little work done to prove these assumptions through especially quantitative methods, this could be a fruitful avenue for future research.

Contextual and Geographical Differences

The usage of the ECI model is primarily based on gaining the knowledge of the contractor early on in the design in order to improve constructability, but the way how ECI is performed differs per country. Scheepbouwer and Humphries (2011) discuss the differences between US, UK and Australia and New Zealand. In the US the usage of ECI is comparable to a construction management at risk and the client has separate contracts with the design engineering part vis-à-vis the contractor. In the UK there is a single contract with the contractor who can subcontract the design. A number of articles discuss how ECI is applied in their country through case studies (e.g., Lenferink *et al.,* 2012; Volker *et al.,* 2018, Wondimu *et al.,* 2018) and many of these articles also discuss that applying the model of ECI is a learning process in which adaptations are made over time that fit better within the local or geographical context.

As much of the current literature focuses on the local context, an interesting approach for future research would be to compare these and analyse the impact of context-bound differences.

Strong Focus on Procurement Phase and Less on Governance

The majority of existing literature focus on the procurement phase of construction projects and leave the execution and governance phases out of scope. The strong emphasis on procurement is primarily focused on the contract, as well as the cost and incentive structures of the project (e.g., Hastie *et al.,* 2017, Laryea and Watermeyer 2016, Volker *et al.,* 2018). Even though Walker and Lloyd-Walker (2012) view ECI as being applicable in all phases from early design to construction, there has been less focus on the governance of these projects. This is confirmed in Chen *et al.,* (2018) who states that literature on collaborative procurement models can be found in two strands: contractual mechanisms and non-contractual mechanisms like leadership, communication and integration. Furthermore, less attention has been paid to the project relationships between the contracting parties, how the project is organized, and how responsibility and decision making is divided between the involved parties. While ECI literature primarily discusses the contractual relationship between the client and the contractor, the other project parties are not often discussed. Based on literature concerning relationship contracting the relationships between the different actors becomes relevant to study in more detail and especially in ECI projects. (Rahman and Kumaraswamy 2004, Scheepbouwer and Humphries 2011).

In order to gain insight in the different actors participating in an ECI project and how collaboration between different parties can be influenced it becomes relevant to not only study the contractor - client relationship, but also the contractor-client-consultant relationship. In order to study this relationship in an ECI context, as well as follow the literature regarding an increased focus on the relationships within a project as previously mentioned, a theoretical approach based on network theory would be one suitable way of expanding the field.

Lack of a Theoretical Contribution

The literature related to ECI doesn't seem to favour one specific publication outlet, although most of the published journal articles were found in publications related to the field of civil engineering and construction management. Over 40 % of the reviewed research was published as conference proceedings. The existing literature on the construction industry and the different forms of relationship contracting are focused on empirical studies and case studies. Most of the analysed literature was focused more on case studies and finding project-specific factors of success and failure than on contributing to a theoretical framework related to the construction industry. Only a fifth of the reviewed articles discussed their theoretical background or contributions to theory while at the same time giving ample attention to questions related more to applied research, such as how to implement ECI in practice. This practice raises questions regarding the contribution potential of the previous research, as the link to theory is weak at the best and missing at the worst. As Flick (2007: 21) says: “in qualitative research we have to build on existing theories and results from empirical research, unless we want to risk being naïve when starting our research”.

As the lack of a theoretical lens is the most important find in this review, this should be the main area of focus for future research endeavours. As the contribution to theory building is one of the main functions of scientific research and one especially

suited for case research (Eisenhardt, 1989), this is an area not to be neglected in the future.

CONCLUSION

In order to gain insight in research concerning ECI, a literature review was performed to identify the core concepts and usage of the ECI model. The main findings of this review relate to four areas: the approach to ECI, context-based differences, focus on the contractual aspects, and a lack of theoretical contributions.

First, this literature review reveals a unified definition of ECI based on a small number of core references. The review also finds that multiple types of methods are applied in ECI studies, with a major focus on qualitative methods and case studies. The benefits and hindrances of the ECI model are clearly defined and many authors refer to the core references and often confirm especially the benefits of early contractor involvement in infrastructure projects. Furthermore, the involvement of contractors in an early design phase can be found in multiple concepts, such as 'partnering' or 'alliancing'. The identified literature related to ECI is focused on practice and empirical cases, which indicates a gap in the existing research related to the usage of quantitative methods.

Second, the literature identifies differences in how ECI is applied in different contexts based on learnings and adaptations in different projects and countries. A possible angle for future research would be to compare these and analyse the impact of context-bound differences.

Third, the literature focuses on the contractual aspects and incentive structures of ECI, while less focus is on how ECI is organized in the project, the division of responsibility and sharing of information amongst the partners. Furthermore, the relation between contractor - client - and engineering consultancy firms is not often discussed. It thus becomes relevant for future work to focus on the governance and the network of multiple partners collaborating in an ECI project.

Finally, an aspect to consider in further analysis is the lack of theoretical foundation for ECI in the construction industry. A theoretical lens anchors the results from empirical data or case studies can contribute to the development of theory, but this link is currently missing.

REFERENCES

Aarseth, W, Andersen, B, Ahola, T and Jergeas, G (2012) Practical difficulties encountered in attempting to implement a partnering approach, *International Journal of Managing Projects in Business*, 5(**2**), 266-284.

Australian Constructors Association (1999) *Relationship Contracting: Optimising Project Outcomes*. Available from https://www.constructors.com.au/wp-content/uploads/1999/02/Relationship-Contracting-Optimising-Project-Outcomes-1999.pdf [Accessed 19/07/2019].

Bourn, J (2007) *Estimating and Monitoring the Costs of Building Roads in England*. Report by the Comptroller and Auditor General, London, UK.

Bygballe, L E, Jahre, M and Swärd, A (2010) Partnering relationships in construction: A literature review, *Journal of Purchasing and Supply Management*, 16(**4**), 239-253.

Chen, L, Manley, K, Lewis, J, Helfer, F, Widen, K (2018) Procurement and governance choices for collaborative infrastructure projects, *Journal of Construction Engineering and Management*, 144(**8**), 1-10.

Eadie, R and Graham, M (2014) Analysing the advantages of early contractor involvement, *International Journal of Procurement Management*, 7(**6**), 661-676.

Eisenhardt, K, M (1989) Building theories from case research, *The Academy of Management Review*, 14(**4**), 532-550.

Eriksson, P E (2008) Procurement effects on coopetition in client-contractor relationships', *Journal of Construction Engineering and Management*, 134(**2**), 103-112.

Grant, M, J and Booth, A (2009) A typology of reviews: An analysis of 14 review types and associated methodologies, *Health Information and Libraries Journal*, 26, 91-108.

Gunn, J (2002) *The Effective Use of Partnering and Alliancing*. London: Minter Ellison Lawyers.

Hart, C (2014) *Doing a Literature Review 1st Edition*. London: SAGE Publications Ltd.

Hastie, J, Sutrisna, M and Egbu, C (2017) Modelling knowledge integration process in early contractor involvement procurement at tender stage - A Western Australian case study, *Construction Innovation*, 17(**4**), 429-456.

Jelodar, M, B, Yiu, T, W and Wilkinson, S (2016) A conceptualisation of relationship quality in construction procurement, *International Journal of Project Management*, 34(**6**), 997-1011.

Jones, B (2014) Integrated Project Delivery (IPD) for maximizing design and construction considerations regarding sustainability, *Procedia Engineering*, 95, 528-538.

Lahdenperä, P (2009) *Allianssiurakka: Kilpailullinen Yhden Tavoitekustannuksen Menettely*, Helsinki: VTT.

Lahdenperä, P (2012) Making sense of the multi-party contractual arrangements of project partnering, project alliancing and integrated project delivery*, Construction Management and Economics*, 30(**1**), 57-79.

Laryea, S and Watermeyer, R (2016) Early contractor involvement in framework contracts, *Proceedings of the Institution of Civil Engineers - Management, Procurement and Law*, 169(**1**), 4-16.

Lenferink, S, Arts, J, Tillema, T, van Valkenburg, M. and Nijsten, R (2012) Early Contractor involvement in Dutch infrastructure development: Initial experiences with parallel procedures for planning and procurement, *Journal of Public Procurement*, 12, 1-42.

MohammadHasanzadeh, S, Hosseinalipour, M and Hafezi, M (2014) Collaborative procurement in construction projects performance measures, case study: Partnering in Iranian construction industry, *Procedia - Social and Behavioural Sciences*, 119, 811-818.

Mosey, D (2009) *Early Contractor Involvement in Early Contractor Involvement in Contracts, Partnering and Project Management 1st Edition*. Oxford: Wiley-Blackwell.

Naoum, S (2003) An overview into the concept of partnering, *International Journal of Project Management*, 21(**1**), 71-76.

Nichols, M (2007) *Review of Highways Agency's Major Roads Programme*. London: Highways Agency.

Pheng, L, S, Gao, S and Lin, J, L (2015) Converging early contractor involvement (ECI) and lean construction practices for productivity enhancement: Some preliminary findings from Singapore, *International Journal of Productivity and Performance Management*, 64(**6**), 831-852.

Rahman, M and Alhassan, A (2012) A contractor's perception on early contractor involvement, *Built Environment Project and Asset Management*, 2(**2**), 217-233.

Rahman, M, M and Kumaraswamy, M, M (2004) Contracting relationship trends and transitions, *Journal of Management in Engineering*, 20(**4**), 147-161.

Scheepbouwer, E and Humphries, A B (2011) Transition in Adopting Project Delivery Method with Early Contractor Involvement, *Transportation Research Record: Journal of the Transportation Research Board*, 2228(**1**), 44-50.

Volker, L, Eriksson, P E, Kadefors, A and Larsson, J (2018) A Case Based Comparison of the Efficiency and Innovation Potential of Integrative and Collaborative Procurement Strategies. *In:* Gorse, C and Neilson, C J (Eds.), *Proceedings of the 34th Annual ARCOM Conference*, 3-5 September 2018, Queen's University, Belfast, UK. Association of Researchers in Construction Management, 515-524.

Walker, D and Lloyd-Walker, B (2012) Understanding early contractor involvement (ECI) procurement forms. *In:* Smith, S.D (Ed.), *Proceedings of the 28th Annual ARCOM Conference*, 3-5 September 2012, Edinburgh, UK. Association of Researchers in Construction Management, 877-87.

EXPLORING THE DESIGNER-CONSTRUCTOR TEAMWORK INTERFACE TO IMPROVE COLLABORATION: A REVIEW OF CURRENT LITERATURE

Hazel Ponton[1], Allan Osborne[2], David Greenwood[3] and Neill Thompson[4]

[1,2&3] *Department of Mechanical and Construction Engineering, University of Northumbria at Newcastle, Newcastle-upon-Tyne, United Kingdom, NE1 8ST, UK*

[4] *Department of Psychology, University of Northumbria at Newcastle, Newcastle-upon-Tyne, United Kingdom, NE1 8ST, UK*

The construction industry has been criticised over several decades for functioning and producing output with low levels of productivity when compared to other manufacturing-based industries. One possible solution to improve productivity is the adoption of collaborative working practices by project teams, particularly designers and constructors during the design phase. Arguments in support of the need to manage the design process effectively during a construction project are well documented. Issues such as providing the client with a sustainable, affordable, quality design that adds value to their business needs, requires attention. Managing the interpersonal interface between designers and constructors during the design phase is a vital requirement of design management practice. Design management is a discipline that requires a thorough understanding of the nature and culture of the different professionals to improve the social behaviours and performance of teams, which in turn may improve project outcomes and thus industrial productivity. The current study, which is part of an ongoing project, presents the position of the design management literature focused on the interpersonal behaviour between designers and constructors. Following a strategically focused review of the extant literature, current themes relevant to Teamwork Quality (TWQ), specific to the designer-constructor interface, are presented. The findings confirm the presence of 14 articles that explore collaborative teamwork behaviour between designers and constructors and that survey methods dominate publications in this area. Few studies capture the power of space and place by observing 'live' industry practice, particularly from a longitudinal perspective. Recommendations include the identification of research themes worthy of future exploration that may assist in teamwork performance concerning productivity. An increase in the use of alternative methodological approaches such as ethnographic and action research is also justified and discussed.

Keywords: behaviour, collaboration, design management, performance, teamwork

INTRODUCTION

The Latham (1994) and Egan (1998, 2002) reports, which were targeted at the UK construction industry, called for greater collaboration and innovation. They have been recently supported by the Farmer Review (2016) that addressed the ongoing problems

[1] hazel.ponton@northumbria.ac.uk

Ponton, H, Osborne, A, Greenwood, D and Thompson, N (2019) Exploring the Designer-Constructor Teamwork Interface to Improve Collaboration: A Review of Current Literature *In:* Gorse, C and Neilson, C J (Eds) *Proceedings of the 35th Annual ARCOM Conference,* 2-4 September 2019, Leeds, UK, Association of Researchers in Construction Management, 324-333.

of fragmentation and adversarial behaviour, including negative working practices in project teams. One of the outcomes of this drive for change is the increase in popularity of contractor-led procurement routes that have led to primary or main contractors taking more responsibility for the design subprocess to improve collaboration, productivity, and to reduce cost (Gray and Hughes 2001). This development has resulted in those who traditionally directed the design subprocess finding themselves as subcontractors participating in multi-disciplinary teams (Greenwood *et al.,* 2008). The effect of these new procurement routes means main contractors are often contractually responsible for and thus need to manage the entire design process. Although the design process accounts for a relatively small proportion of the overall project cost, it has a significant impact on the characteristics, construction, and whole-life cycle cost of projects. The effective management of the design process is vitally important to the success of a construction project (Tjell and Bosch-Sijtsema 2015).

Emmitt and Ruikar (2013) have shown that due to the uncertainty and complexity of construction projects, the most critical inter-relationship within a site-specific, project-based organisational structure is the dynamic relationship that exists between the design and construction subprocesses. Eynon (2013) has explored the interdependent relations between the actors involved with these subprocesses—namely designers and constructors—from a holistic perspective to understand the professional disciplines, i.e., concerning their views, backgrounds, and preferred working practices. He introduced the notion of 'tribes' as a means to distinguish between the two disciplines, surmising that silos or positions of 'tribe of design' and 'tribe of construct' are different in several ways: Ways that have the potential to create conflict and hinder effective performance (see Table 1).

Table 1. Eynon's tribes of design and construct

Tribe of Design	Tribe of Construct
Iterative	Linear
Possibilities	Cost-driven
Ambiguous	Deadlines
Options	Schedule
Visual	Practical
Creative	Certainty
Intuitive	Factual

Eynon (2013) demonstrates the opposing traits of the tribes: Iterative versus linear; ambiguous versus factual; and creative versus practical. Not only are the relations between designers and constructors based on contractual boundaries, which may result in adversarial behaviour and conflict, but they are also influenced by different values, culture, education, and history. These opposing perspectives have the potential to lead to problems that may impact on the performance of the project team, and ultimately the project, mainly while working under pressure to complete a bespoke construction project on time and to cost.

Although it is acknowledged that the distinct phases of a construction project need to be efficiently and effectively managed, the tenet of the current study is that priority must be given to the design phase. Considering the legacy of financial responsibility, the design process holds if not successfully executed, it is argued that the interactions between designers and constructors need to be effectively managed to safeguard the success of construction projects for the benefit of all stakeholders.

The unique focus of the current study is twofold. First, to systematically review the extant literature to identify publications that explore the interactions between constructors and designers at an individual (micro level) in the context of contractor-lead design projects. Second, from the outcomes of the first step, to review the research methods used in the identified publications. By reviewing the literature in a systematic way, the current study aims to reveal previously unidentified knowledge gaps and to evaluate the methods used to inform knowledge in this domain.

SYSTEMATIC LITERATURE REVIEW

A systematic literature review was chosen as the most appropriate technique to gain an overview of earlier studies in a structured way (Tranfield *et al.,* 2003). Jahan *et al.,* (2016) have explained systematic reviews are ranked very high in research. They go on to explain the method provides a complete summary of the current literature relevant to a research question.

During the study two databases were used: Scopus (Sco), and Web of Science (WoS). Both databases were chosen because they contain a large number of high quality peer-reviewed journals that publish work focused on the construction industry. To focus on the most recent data, only journal papers and conference papers published since 2000 were chosen.

A systematic, extensive search was completed under the 'title/abstract/keyword' field in the databases. The following Boolean topic word pattern was used during the initial search: ("construction industry" OR "building industry" OR "architectural engineering and construction") AND (design AND management) AND (teams OR teamwork) AND (communication) AND (behaviour OR behavior) AND (dynamics).

The initial search identified 150/15 (Sco/WoS) articles in the different databases. These articles were then reduced to 132/1 (Sco/WoS) after discarding irrelevant articles or publications, e.g., biochemistry and medicine, and multiple articles across both databases. The results were then filtered by reading the abstract, keywords, and title, discarding those publications that were unrelated to the focus of the topic.

The result was a list of 14 publications. The fact that only 14 articles met the criteria for the dataset was surprising; however, it indicates that the relationship between designers and constructors has received sparse attention.

The next step in the process was to establish a set of constructs to allow the dataset to be coded. These constructs allow for the identification of possible gaps in the existing literature by applying an analytical framework.

Using Analytical Categories

To be able to identify knowledge gaps concerning effective, collaborative teamwork interactions between designers and constructors, the current study adopted the theoretical perspective of Teamwork Quality (TWQ). TWQ is a measure of collaboration in teams (Hoegl and Gemuenden 2001) and was considered to be an appropriate theoretical lens from which to study the selected publications that explore the interactions between constructors and designers. Increased collaboration is the countermeasure suggested by Latham (1994), Egan, (1998, 2002), and Farmer's (2016) reports. According to Hoegl and Gemuenden's (2001) work, TWQ has the following six constructs:

- Communication: Issues such as frequency, formalisation, structure, and openness of information exchange.

- Coordination: Issues such as a degree of common understanding, interrelatedness, working together, delegated, and parallel tasks.
- A balance of member contributions: Issues such as the contribution of all task-relevant knowledge and experience.
- Mutual support: Issues such as cooperative rather than the competitive frame of mind and mutual respect.
- Effort: Issues such as shared expectations regarding effort, workload, sharing, and prioritising.
- Cohesion: Issues such as interpersonal relationships, commitment, togetherness, team spirit, belonging, and trust.

The resulting 14 papers were studied, reviewed, and coded against the above six TWQ constructs within the boundaries of the primary aim of the publication (see Table 2).

FINDINGS

Communication

The communication category emphasises the importance of member communication in a collaborative team setting. Included in the TWQ construct are issues such as the frequency, formalisation, structure, and openness of information exchange. Six articles were found where the primary focus was communication, with perspectives or participation from designers and constructors (as well as other participants, i.e., the client). Two of these articles, one by Gorse and Emmitt (2003) and one by Gorse and Emmitt (2007), use 'live' meeting observations to categorise and interpret project team member behaviour. The studies observed meetings over some time, allowing data to be collected longitudinally, which adds to the richness and quality of the findings.

One of the findings discovered by Gorse and Emmitt (2007) is the lower than expected levels of negative emotions, and critical discussions present during the meetings. Their research suggests that low levels of adversarial interaction may impact on the project team's ability to challenge problems and create necessary conflict for effective performance. The necessary conflict is an essential requirement for a project to achieve a successful project outcome. Emotions and conflict are areas that require greater understanding.

With the primary focus on measuring innovation in the construction industry, Gambatese and Hallowell (2011) adopted interviews (following initial questionnaires) to collate data about some on-going and past projects. The findings from the article included the identification of innovation as a method to improve project team member communication, specifically concerning integrating the design and construction disciplines. Two articles in the communication category explored innovative technologies to improve project collaboration and effectiveness. These were Hatem *et al.,* (2012) and Hosseini *et al.,* (2018). Both articles considered the effectiveness of interdisciplinary team members working virtually and face-to-face. Using a simple simulation of a design task, Hatem *et al.,* (2012) found that project team members could perform as effectively, if not slightly better, when interacting virtually.

Table 2 Articles by categories and their key features

Category	Author	Data collection	Journal	Primary research theme	Findings
Communication	Gorse and Emmitt (2003)	Observe project meetings	Engineering, Construction and Architectural Management	Interpersonal communications during project meetings.	Bales' IPA can be used to identify the characteristics and effects of team member behaviour during project meetings.
	Gambatese and Hallowell (2011)	Interviews (initial questionnaires)	Construction Management and Economics	Enabling and measuring innovation during construction projects.	Successful innovation leads to better communication as well as the integration of the design and construction disciplines.
	Hatem *et al.*, (2012)	Simplistic simulation	Advanced Engineering Informatics	Comparing the effectiveness of face to face and computer-mediated collaboration.	People collaborate as effectively using IT communication methods as working face to face.
	Hosseini *et al.*, (2018)	Interviews	Construction Innovation	Impacts of virtual working on the effectiveness of construction project teams.	A novel insight of virtual and hybrid project team's performance. The importance of face-to-face interactions.
	Gorse and Emmitt (2007)	Design meeting observations	Construction Management and Economics	Communication behaviour during management and design team meetings.	Negative emotions and critical discussions were so low to suggest a lack of necessary conflict.
	den Otter and Emmitt (2007)	Mixed method (interviews, checklists, data log and documents).	Engineering, Construction and Architectural Management	Exploring team communication: Balancing synchronous and asynchronous communication in design teams	Common understanding requires interactions to stimulate the team's social development.
Coordination	Forgues and Koskela (2009)	Longitudinal case study (mixed qualitative methods)	International Journal of Managing Projects in Business	Influence of collaborative procurement on the performance of integrated design teams.	Traditional procurement hinders team efficiency, while new procurement modes have a positive impact.
	Lingard *et al.*, (2012)	Mixed method (observations, interviews and documents)	Construction Management and Economics	Understand the integration issues of designing for construction health and safety.	The complexity of integrating H&S into construction design, particularly during the design decision-making process.

cont.

Category	Author	Data collection	Journal	Primary research theme	Findings
The balance of member contributions	Zhang and Ng (2013)	Questionnaire	Journal of Construction Engineering and Management	An integrative understanding of factors affecting individual knowledge-sharing intention in construction teams.	Professionals are motived to share knowledge by their expectations of developing work-related confidence and capability.
	Pirzadeh and Lingard (2017)	Interviews	Journal of Management in Engineering	Social interactions between project actors about designing for health and safety.	Improvements in H&S design occurred when actors with H&S knowledge join the relevant social networks.
Mutual support	White and Siu-Yun Lui (2005)	Questionnaire	Strategic Management Journal	Cost of cooperation and control in alliances of construction projects.	Cooperation has a cost with working collaboratively with a partner, in an alliance. This cost needs to be recognised.
	Anvuur and Kumaraswamy (2007)	Literature review	Journal of Construction Engineering and Management	Partnering and alliancing in construction projects.	Partnering can create conditions for optimal intergroup contact, increase cooperation and improve team performance
Effort	No findings				
Cohesion	Ponton *et al.,* (2018)	Design meeting observations	ARCOM conference proceedings	Understanding the dynamics of design-construct behaviour through laughter and humour.	Collegiality and group dynamics may foster increased collaboration and the better integration of ideas among team members.
	Karlsen *et al.,* (2008)	Interviews	International Journal of Project Organisation and Management	The role of trust in project-stakeholder relationships	Effective communication and reliable behaviour are necessary to build trust in a project team.

On the other hand, Hosseini *et al.,* (2018) gathered data using interviews. They found that team orientation, leadership, performance, and member satisfaction were all detrimentally affected by working virtually. The difference in findings may be attributed to the different data collection methods, i.e. a simple simulation and interviews. den Otter and Emmitt (2007) contribute to the same debate concerning effective forms of communication through their exploration of communication via synchronous and asynchronous means. The article adopted a mixed method approach, which included interviews and project data and documentation scrutiny. The article did not singularly identify either means of communication as the most effective, rather the identification and use of the most appropriate method as a fundamental aspect of team performance. However, the publication also stresses the need for personal

interaction to accommodate common understanding and to stimulate the team's social development. The issue of successful collaboration between designers and constructors during the design process currently recognise the need and benefits of virtual working. However, the issues of how actors interact virtually still require further investigation.

Coordination

This category refers to issues such as the degree of common understanding, interrelatedness, integration, and working together. Two articles were identified as having the primary research focus in this area: These were Forgues and Koskela (2009) and Lingard *et al.,* (2012). Interestingly, both articles adopted a qualitative, mixed-method approach as their means of collecting data. Forgues and Koskela (2009) investigate the influence of collaborative procurement on the performance of integrated design teams. They discovered that traditional procurement hinders team efficiency, while new procurements modes, i.e., contractor-led design, have a positive impact on team performance due to an increased opportunity to practice interdisciplinary collaborative working. Lingard *et al.,* (2012) support the benefits of working collaboratively. However, they also recognise the complexities of doing so, specifically concerning designing for H&S. Teamwork collaboration is widely recognised across literature; however, how to resolve the complexities of this kind of work still requires further investigation.

Contribution

The balance of member contributions category refers to issues such as team members contributing all their knowledge and experience to a task, particularly when members of the team have expertise in different functional areas. Both of the articles found in this category are interested in knowledge, particularly knowledge sharing. Zhang and Ng (2013) discovered through questionnaires that the motivation of construction professionals to share knowledge links to their expectations of developing work-related confidence and capability. Pirzadeh and Lingard (2017) also focused on knowledge sharing but from a different perspective. Data gathered from interviews were used to identify social networks that highlighted the improvements in H&S aspects of the design once actors with construction expertise joined the social network and input knowledge into the design process. Again, the literature seems to support the importance of collaborative working. Similarly, it seems to support the notion that rich data can be established from an understood of a 'live' setting.

Mutual Support

This category is defined by issues such as team members operating with a cooperative rather than the competitive frame of mind. The construct is also interested in issues such as mutual respect between team members and the need to develop other team members' ideas and contributions, rather than trying to outdo each other. Two articles with different perspectives and different data collection methods were found to have their primary research focus in this construct. White and Siu-Yun Lui (2005) collected data from questionnaires to verify the idea that although cooperation in an alliance is important for collaboration, cooperative teamwork comes with a financial cost. This cost needs recognition for future partnering ventures. Anvuur and Kumaraswamy (2007) took an alternative approach to research cooperation by focusing on the benefits of partnering, principally through carrying out a literature review; then, ascertaining that partnering can create conditions for optimal intergroup contact, increase cooperation, and improve team performance. Again, the data

collection methods adopted in the category lacked the use of 'live' data, although they do support the practice of working collaboratively - as long as the cost is recognised and included in a partnering agreement.

Effort

This category is concerned with issues such as shared expectations regarding effort, workload, sharing, and prioritising. The systematic literature gathering process found no articles where 'effort' is the primary focus of the research. This is an interesting finding because the designer-constructor interface depends on shared and understood expectations regarding the design, which has clear workload implications.

Cohesion

The final category is concerned with team cohesion. In the context of TWQ, cohesion is relevant to interpersonal relationships, commitment, togetherness, team spirit, belonging and trust. Two articles fall into this category. First, Karlsen *et al.,* (2008) explore the role of trust in project stakeholder relationships. The findings include the need for effective communication and reliable behaviour to build trust. The research gathers data from interviews. The second article in this category is by Ponton *et al.,* (2018). Observations of design team meetings form the data collection, with attention paid to critical events of joint laughter. Collegiality and group dynamics were found to possibly increase collaboration effectiveness and the better integration of ideas among team members. The use of 'live' data allowed for the capture of natural laughter events in their setting, rather than individual, retrospective perspectives captured from surveys. The importance of productive team cohesion as an ingredient of successful collaborative working is demonstrated in both articles.

DISCUSSION AND RECOMMENDATIONS

Surprisingly, a relatively low number of publications were found (14). The number highlights a need for greater understanding about all the TWQ constructs of communication, coordination, the balance of member contributions, mutual support, effort and cohesion - all in the context of designer-constructor behavioural interactions during contractor-led projects.

In light of the increasing use of virtual communication technologies, highlighted by a number of articles (see Hosseini *et al.,* 2018 and Hatem *et al.,* 2012) in the review and the opposing positions of the team members identified by Eynon (2013), finding a way to make virtual interaction as productive and collaborative as possible, if not more productive than face-to-face approaches, while maintaining necessary social interactions and team social development, is an area for future investigation.

A further consideration is the findings by Emmitt and Gorse (2007) into the lower than expected levels of negative emotions and critical discussions present during design meetings. Eynon (2013) identifies the 'tribe of design' to include the need for creativity and possibilities, but if these traits are not present during interactions between designers and constructors through a lack of critical discussions, then the potential for the team to produce innovative solutions may be limited. Emotions and conflict are important considerations. Low levels of adversarial interaction may impact on the project team's ability to challenge problems and create the necessary conflict for effective performance, collaboration, and innovation.

Finally, the data collection approaches of the publications included a variety of methods. The most common being interviews, with others including observations of

'live' meetings, review of project documents, and questionnaires. In terms of making recommendations for future research, a qualitative 'in-vivo' approach allows for a rich contextual understanding of the interactions between designers and constructors. By carrying out qualitative 'in-nivo' data collection longitudinally, perhaps a deeper understanding of interactions can be accomplished. This would suggest applying approaches, such as ethnographic and action research. Neither of these approaches has been adopted in this specific context before and could, therefore, provide previously 'unseen' worthwhile insights in future studies.

Acknowledging the restricted focus on the behaviour of designers and constructors in the current study, the following future research themes have been identified.

- A broader examination of the interactions between designers and constructors, in relation to opposing working practices and the need for collaborative working. The examination may include the issues of communication, coordination, the balance of member contributions, mutual support, effort and team cohesion.
- In-depth analysis of virtual working practices between designers and constructors to identify potential issues caused by opposing working practices, which stem from different values, culture, education, and history.
- Further examination of the impact of emotions and conflict on innovative, collaborative design team practices.
- Use of longitudinal 'live' data, i.e., ethnographic and action research, to capture the power of space and place.

REFERENCES

Anvuur, A M and Kumaraswamy, M M (2007) Conceptual model of partnering and alliancing, *Journal of Construction Engineering and Management*, 133(**3**), 225-234.

Egan, J (1998) *Rethinking Construction, Report of the Construction Task Force on the Scope for Improving the Quality and Efficiency of the UK Construction Industry*. Department of Environment, Transport and Regions (DETR), London: HMSO.

Egan, J (2002) *Rethinking Construction: Accelerating Change, Strategic Forum for Construction*. London: HMSO.

Emmitt, S and Ruikar, K (2013) *Collaborative Design Management*. Abingdon: Routledge.

Eynon, J (2013) *The Design Manager's Handbook.* Chichester: CIOB/John Wiley and Sons.

Forgues, D and Koskela, L (2009) The influence of a collaborative procurement approach using integrated design in construction on project team performance, *International Journal of Managing Projects in Business*, 2(**3**), 370-385.

Gambatese, J A and Hallowell, M (2011) Enabling and measuring innovation in the construction industry, *Construction Management and Economics*, 29(**6**), 553-567.

Gorse, C A and Emmitt, S (2003) Investigating interpersonal communication during construction progress meetings: Challenges and opportunities, *Engineering, Construction and Architectural Management*, 10(**4**), 234-244.

Gorse, C and Emmitt, S (2007) Communication behaviour during management and design team meetings: A comparison of group interaction, *Construction Management and Economics*, 25(**11**), 1197-1213.

Gray, C and Hughes, W (2001) *Building Design Management*. Oxford: Butterworth-Heinemann.

Greenwood, D, Walker, P and Walker, A (2008) The world turned upside-down: Architects as subcontractors in design-and-build contracts. *In:* Dainty, A (Ed.), *Proceedings of the 24th Annual ARCOM Conference*, 1-3 September 2008, Cardiff, UK. Association of Researchers in Construction Management, Vol. 1, 507-16.

Hatem, W A, Kwan, A and Miles, J (2012) Comparing the effectiveness of face to face and computer mediated collaboration, *Advanced Engineering Informatics*, 26(**2**), 383-395.

Hoegl, M and Gemuenden, H G (2001) Teamwork Quality and the Success of Innovative Projects: A Theoretical Concept and Empirical Evidence, *Organization Science*, 12(**4**), 435-449.

Hosseini, M R, Bosch-Sijtsema, P, Arashpour, M, Chileshe, N and Merschbrock, C (2018) A qualitative investigation of perceived impacts of virtuality on effectiveness of hybrid construction project teams, *Construction Innovation*, 18(**1**), 109-131.

Karlsen, J T, Graee, K and Massaoud, M J (2008) The role of trust in project-stakeholder relationships: A study of a construction project, *International Journal of Project Organisation and Management*, 1(**1**), 105.

Latham, M (1994) *Constructing the Team*. London: HMSO.

Lingard, H C, Cooke, T and Blismas, N (2012) Designing for construction workers' occupational health and safety: A case study of socio-material complexity, *Construction Management and Economics*, 30(**5**), 367-382.

den Otter, A and Emmitt, S (2007) Exploring effectiveness of team communication: Balancing synchronous and asynchronous communication in design teams, *Engineering, Construction and Architectural Management*, 14(**5**), 408-419.

Pirzadeh, P and Lingard, H (2017) Understanding the dynamics of construction decision making and the impact on work health and safety, *Journal of Management in Engineering*, 33(**5**), 5017003.

Ponton, H, Osbourne, A, Greenwood, G and Thompson, N (2018) Understanding the Dynamics of Construction Design Team Meetings through Joint Laughter. *In:* Gorse, C and Neilson, C J (Eds.), *Proceedings of the 34th Annual ARCOM Conference*, 3-5 September 2018, Queen's University, Belfast, UK. Association of Researchers in Construction Management, 88-97.

Tjell, J and Bosch-Sijtsema, P M (2015) Visual Management in mid-sized construction design projects, *Procedia Economics and Finance*, 21, 193-200.

Tranfield, D, Denyer, D and Smart, P (2003) Towards a methodology for developing evidence-informed management knowledge by means of systematic review, *British Journal of Management*, 14(**3**), 207-222.

White, S and Siu-Yun Lui, S (2005) Distinguishing costs of cooperation and control in alliances, *Strategic Management Journal*, 26(**10**), 913-932.

Zhang, P and Ng, F F (2013) Explaining Knowledge-sharing intention in construction teams in Hong Kong, *Journal of Construction Engineering and Management*, 139(**3**), 280-293.

EXPLORING THE VALUE OF DEMOLITION CONTRACTOR INVOLVEMENT AT THE DESIGN STAGE OF CONSTRUCTION

Yazan Osaily[1], Alex Copping[2], Stephen McCann[3] and Tamil Uddin[4]

[1&2] *Department of Architecture and Civil Engineering, University of Bath, Bath BA2 7AY, UK*

[3] *Perses, 36 Venturefair Drive, Edinburgh, EH17 8WD, UK*

[4] *McGee Group, Alto Tower, London SE1 9PG, UK*

It is clearly understood that the design teams have a critical role to play in achieving circularity in the built environment. However, little attention has been given to the demolition industry and its contribution at the design stage of construction. The purpose of this paper is to investigate the role of the demolition industry in the movement towards the circular economy through exploring the benefits and challenges of involving demolition contractors at the design stage of construction. This study reports the findings from 12 in-depth interviews undertaken with professional demolition practitioners. The following questions were asked: Are there benefits to involving a demolition contractor at the design stage? What roles and responsibilities might be appropriate for the demolition contractor at the early stages of design? What knowledge does the demolition contractor possess that is of value to designers and clients? And what challenges might arise? The findings show that early demolition contractor involvement is more likely to ensure that end-of-life factors are considered at early phases of design. The input of a demolition contractor at the design stage will encourage designers to design for deconstruction; thus, fulfilling a closed-loop concept. However, a series of challenges were also revealed. Results show that adversarial relationships, cost, and time are the biggest challenges to involving a demolition contractor at the design stage. This study shows the essential need to revise the current linear models followed within the construction cycle and articulates the important role the demolition industry has in the continued movement towards a circular economy.

Keywords: Early Contractor Involvement, deconstruction, demolition

INTRODUCTION

The concept of the circular economy in the built environment is to keep materials and components at their highest value either by direct re-use in another building, or by 'upcycling' - retaining or even increasing their value (Lemmens and Luebkeman, 2016). The ultimate aim is to create a regenerative built environment that prioritise retention and refurbishment over demolition and rebuilding (Cheshire, 2016). One of the core principles of the movement towards a circular economy approach is through collaboration across the construction cycle (Leising *et al.,* 2018). Many reports have investigated the vital role of designers in transitioning towards a circular approach (Lemmens and Luebkeman, 2016; Cheshire, 2016), as many believe that change

[1] yo252@bath.ac.uk

Osaily, Y, Copping, A, McCann, S and Uddin, T (2019) Exploring the Value of Demolition Contractor Involvement at the Design Stage of Construction *In:* Gorse, C and Neilson, C J (Eds) *Proceedings of the 35th Annual ARCOM Conference,* 2-4 September 2019, Leeds, UK, Association of Researchers in Construction Management, 334-343.

should start at the beginning of life of the construction cycle. Also, the importance of integrating construction knowledge into the design process has long been recognised by the construction industry (Laryea and Watermeyer, 2015). As a result, many researchers have investigated the essential role of involving contractors at early stages of the project (Song *et al.,* 2009; Rahman and Alhassan, 2012; Sødal *et al.,* 2014; Laryea and Watermeyer, 2015) and this is known as Early Contractor Involvement (ECI). However, the role of the demolition contractor is often neglected and not many have emphasised the importance of involving demolition in the construction cycle. Some studies allude to the importance of consulting a demolition contractor at the design stage. They considered it as a critical success factor for diverting end-of-life waste from landfills (Akinade *et al.,* 2017) and to delivering demolition projects successfully (Osaily *et al.,* 2018). These studies, however, have not addressed the benefits and challenges to engaging a demolition contractor at early stages of design and its impact on the movement towards the circular economy. This study therefore sets out to fill this gap. As a starting point the ECI literature is outlined as it forms a sound foundation for the study. Very little academic literature has been published on early demolition contractor involvement.

Early Contractor Involvement

Early contractor involvement (ECI) in defined as a relationship between a contractor and an owner or a designer that engages the contractor from the early design stage and allows the contractor to contribute construction knowledge and experience to design (Song el al., 2009). The concept of ECI emerged in the early 2000s in the UK due to many reasons. To begin with, many studies identified current traditional procurement methods as broken and in need for revision (Bundgaard *et al.,* 2011), because designers and clients intend to make key decisions long before the engagement of the contractor. Arditi *et al.,* (2002) noted that clients and designers make those decisions while lacking construction experience and awareness of construction knowledge. Additionally, Song *et al.,* (2009) argues that their decisions are predominantly driven by factors such as aesthetics, functionality, and budget. Therefore, and with the ever-growing construction projects complexities, this method is no longer feasible, as it diminishes the potential input for experts (i.e. contractors) at early stages (Song *et al.,* 2009). According to Bundgaard *et al.,* (2011), experts should be engaged from the beginning of the project; they should be proactive rather than reactive to designers' decisions.

Benefits of Early Contractor Involvement

The prospects of benefits are likely to increase with the implementation of ECI (Mosey, 2009). The engagement of contractors at early stages of projects and their interaction with the developers and consultants whilst integrating their knowledge would reflect positively on the project from many aspects (Sze Boon, 2015). One of the key areas that are improved through ECI is better management of risks (Sødal *et al.,* 2014; Boon, 2015); engaging contractors at the design stage would enhance the team's risk perception and would enable a more thorough identification and more quantification of risks (Sødal *et al.,* 2014). Thus, overall management of risks is improved. Additionally, one of the significant benefits of ECI is contractors input to design. Contractors can implement their knowledge and expertise of construction materials, methods and local practice, to develop improved design (Rahman and Alhassan, 2012). Also, contractors input to design have a direct impact on their own construction performance (Song *et al.,* 2009), in terms of cost, time, quality and

safety, as they are responsible for the actual construction works (Rahman and Alhassan, 2012). More benefits of ECI are shown in table 1.

Challenges of Early Contractor Involvement

Seeing as ECI implementation necessitates a radical change in the industry moving away from traditional practices (Song *et al.,* 2009); the implementation of ECI is thus faced by many challenges. Contrasting from traditional tender approaches, ECI process requires the commitment of everyone involved including developers, consultant team, and contractors (Boon 2015).

Table 1: Benefits for Early Contractor Involvement

	Benefits of ECI	Source
1.	Better integration amongst the project stakeholders at the conceptual stage of the project, enabling the input of contractors to be brought into the design process.	Mosey (2009)
2.	Identification and proposed approaches to overcome critical project constraints and risks	Boon (2015)
3.	Greater awareness of risk and understanding	Mosey (2009)
4.	Contractors knowledge will assist in developing a more realistic and reliable schedule and cost estimate for the project.	Laryea and Watermeyer (2015)
5.	Improves construction methodology and technology	Sødal et al. (2014)
6.	Provide better forecast of project outcomes	Rahman and Alhassan (2012)
7.	Joint problem-solving addressing unknowns	Bundgaard et al. (2011)
8.	Early involvement of contractor ensures that construction factors are considered in the decision-making.	Sødal et al. (2014)

Thus, it will require a paradigm shift for all parties involved. There is an essential need for a change in culture as well as a change in the traditional ways of working (Bundgaard *et al.,* 2011). Additionally, it could be challenging to ensure commitment and collaboration from everyone involved (Sødal *et al.,* 2014); according to Rahman and Alhassan (2012), the involved parties might be unwilling to show commitment to build a friendly relationship with each other, which will lead to instability in the working environment, lack of trust and transparency, and lack of a win-win attitude. Furthermore, one of the key issues with ECI implementation is the lack of knowledge of the process itself that causes construction parties to avert from the process (Mosey, 2009). Song *et al.,* (2009) considered the resistance to culture change as the biggest barrier to the implementation of ECI; this is resulted by lack of understanding of the concept and its benefits. Table 2 illustrates some of the challenges found in literature for ECI implementation.

METHODOLOGY

An exploratory method was suitable for this research as the concept of early demolition contractor involvement is still in its infancy. Data was collected through conducting 12 in-depth face-to-face interviews with experts in the demolition industry including demolition contractors, clients, and client's representatives. Selecting the participants was achieved through judgement sampling technique, or as also known purposive technique (Merriam, 1998). It is a technique typically used in a qualitative research to select the group of participants based on the qualities they possess regarding a phenomenon of interest (Patton, 2002) to gain an in-depth understanding of the phenomenon under investigation (Creswell and Clark, 2011). Therefore, the process of selecting the participants took into consideration their knowledge and experience regarding the researched area (i.e. demolition).

Table 2: Challenges to Early Contractor Involvement

	Challenges of ECI	Source
1.	Absence of a Win-Win attitude	Rahman and Alhassan (2012)
2.	Resistance to cultural change	Boon (2015)
3.	Lack of understanding of the concept and its benefits; lack of explicit case studies illustrating the proper way of implementation	Song et al. (2009)
4.	Lack of trust and transparency amongst project team members	Bundgaard et al. (2011)
5.	Smaller sized companies may not be able to warrant ECI, as it may involve unnecessary charges	Mosey (2009)
6.	Some clients may not be willing to bear the extra cost incurred through ECI	Sødal et al. (2014)
7.	The challenge of who should lead the process in the early phases and who has the decision power	Rahman and Alhassan (2012)
8.	The challenge of requiring the commitment of all project participants	Sødal et al. (2014)

Thus, all the selected participants have a minimum of 20-year experience in the demolition industry or are directors at their company. Additionally, all the participants come from construction background; their combined knowledge of both construction and demolition made them competent and qualified them to answer the researched question. The interview questions were developed after exploring ECI benefits and challenges. This equipped the researcher with sufficient knowledge to develop the interview questions, to better govern the course of the interview, and to provide examples of potential benefits and challenges in case the respondents were uncertain. At the beginning of each interview, the concept of early demolition contractor involvement was proposed to the participant, and then the questions were asked in a semi-structured manner to help capture a more detailed narrative; thus, allowing the participants to speak freely about the subject and express their thoughts without limiting their answers (Laryea and Watermeyer, 2015). All interviews were recorded, transcribed and then analysed using thematic analysis. Thematic analysis is a method used to analyse, identify, and report patterns (themes) within data (Guest *et al.,* 2014). In order to find potential themes, the research adopted Braun and Clarke (2006) process. The process begins with getting familiar with the transcribed content in order to generate codes. The identification of the themes was then undertaken. All data relevant to a specific theme was grouped together in order to build up a convenient story regarding that theme. The process of generating codes and themes from the interviews was done using spreadsheets.

RESULTS

Introducing Early Demolition Contractor Involvement

Early demolition contractor involvement (EDCI) is a new concept introduced in this paper, which is inspired by the ECI contracting method. EDCI refers to the relationship between a demolition contractor and an owner, or a designer which involves a demolition contractor at the design stage of construction. Thus, allowing the demolition contractor to contribute end-of-life knowledge and experience to design. Direct demolition contractor involvement with designers at early stages fosters better cooperation between both parties and enable end-of-life factors to be considered at the design stage. Thus, leading to many benefits across the construction cycle. The implementation of EDCI, however, has many implications; the benefits and challenges of the new concept are explained below.

Benefits of Early Demolition Contractor Involvement

Ten main benefits for EDCI were identified from the interviews conducted. The majority of the benefits have an impact on the end-of-life phase solely. These benefits

are illustrated in Figure 1. The highest-ranking benefits of EDCI are: (1) ensuring end-of-life factors are considered at the design stage, (2) the development of an integrated deconstruction methodology for whole of life cycle, (3) engagement with demolition contractors and the wider design team improves understanding and appreciation of roles and responsibilities and associated expertise, (4) direct contribution to planning applications concerning end-of-life phase, and (5) improved risk assessment for end-of-life phase with design teams. Other interesting benefits which have direct impact on the movement towards the circular economy were obtained. All participants who were aware of the circular economy agreed upon the following two benefits .Firstly, engagement with demolition contractors by design and construction professionals raises the profile of the circular economy and increases adoption of suitable process and practice. Also, engaging a demolition contractor at the design stage fulfils a closed-loop concept due to the valuable advice given by demolition contractors concerning choices of materials to designers.

Challenges to Early Demolition Contractor Involvement

In contrast to the benefits, ten challenges were also identified to the implementation of EDCI. Figure 1 articulates those challenges. Two main challenges were agreed by all participants: (1) clients would not be willing to take the burden of paying the extra cost for the expertise of the demolition contractor, and (2) the fear of potential clash between the involved parties. Other high ranked challenges include: (3) the industry is renowned for its resistance to change, and therefore would not be willing to accept EDCI concept easily. (4) The creativity of designers might be reduced as demolition contractors would concentrate on simplifying the demolition process, thus resulting in them demanding a simpler design. (5) The expertise of the demolition contractor is undervalued by other construction professionals, as a result, his/her opinion might not be heard by other parties. An interesting challenge brought up by few participants was the fact that engaging a new stakeholder at the design stage will necessitate a change in practice, thus establishing new legislations, standards, and forms of contracts may be required.

Further to the benefits and challenges shown in Figure 1, the respondents were asked to identify key areas where their knowledge could be contributed at the design stage. As a result of the exercise, six areas were highlighted: (1) advice on choices of materials, (2) advice on recycling and reuse, (3) develop a deconstruction methodology, (4) develop a risk assessment plan for the deconstruction process, (5) develop a site access plan for the deconstruction process - which includes best access for machinery, vehicles, skips, and cranes to keep pedestrians and vehicles apart, minimise vehicle movement on site, and to speed up the process of moving materials in and out site - and (6) advice on building design. All participants agreed that through experience, the demolition contractor knows what materials are easily dismantled and what are not, and what materials are easily recycled and what are not. Consequently, demolition contractor's advice to designers concerning choices of materials and recycling and reuse is considered invaluable. See figure 1.

DISCUSSION

Similar to ECI, one of the key motivations for the implementation of EDCI, is the fact that clients and designers intend to make key decisions that have vital impact on the end-of-life phase whilst lacking proper understanding of end-of-life expertise and awareness of demolition knowledge. It is stated under the Construction Design and Management (CDM) 2015 regulations that designers have to propose a deconstruction

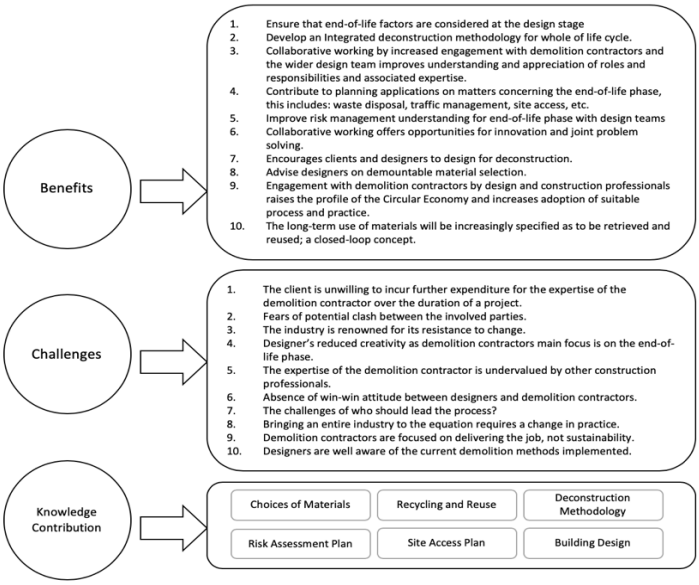


Figure 1: EDCI benefits, challenges, and key areas where a demolition contractor's knowledge could be contributed (benefits and challenges are listed based on their ranking score for the total number of mentions by the participants in their interview).

plan for their designed buildings (Joyce, 2015). However, in a unanimous agreement the participants agreed they never had obtained a deconstruction plan from clients despite the CDM regulations. The majority of the interviewees reflected on this and mentioned that designer decisions are primarily driven by factors such as aesthetics and cost, without having an end in mind. This is also backed up by literature in Song *et al.,* (2009) where the study mentions that designer's decisions are mainly induced by factors such as aesthetics, functionality, and budget. Participant 7 (contracts manager) mentioned in this regard:

> Designers under CDM 2015, there is a pre-requisite that they need to prepare a deconstruction plan for the building. They however don't know how to do it. When a demolition contractor is involved, he will develop the deconstruction methodology. He understands. He could put a footnote at each design element. He could also do a little risk assessment on each design element.

The demolition contractor, therefore, with profound experience could develop a deconstruction plan for any designed building. Additionally, participant 1 (environmental manager) added regarding the decisions made by designers and clients at early stages:

> You see all these buildings that are being built right now? It is all composite structures. So, in terms of recycling the materials it is going to become very difficult. How do you expect the circular economy to work in the upcoming years?

This is also the opinion of the majority of the participants. They expect demolition to become more complicated in the upcoming years in terms of recycling and reusing of materials. Currently, buildings which are being demolished were built in 1940's to 1960's which predominantly consist of simple materials that are easily retrieved, recycled, and reused (Guy and Shell, 2002). However, newly built buildings are generally formed of composite structures where many mastics and adhesives are used. Such materials have less value or no value at all. It would be extremely difficult to separate the materials and extract any value from them in the future. One of the core concepts of the circular economy is to fulfil a closed-loop concept, but how would this be achieved, if in the upcoming years, the industry expects to produce more waste?

Therefore, it is critical to begin designing with an end in mind, and the implementation of EDCI would encourage designers to design for deconstruction.

Another key motive for EDCI implementation is the current calls for the movement towards the circular economy. Such movement will not prosper without involving the entire construction cycle in the process (Leising *et al.,* 2018). Extant literature calls for the need for a radical change in the current methods implemented to design buildings (Lemmens and Luebkeman, 2016; Cheshire, 2016). Such reports display the need to innovate the way buildings are designed through following circular economy principles and to begin designing out of waste. Whilst a change in design is vital, such movement however, is aspiring to change the whole construction cycle through centring their focus on one perspective without involving other key parties within the cycle, such as the demolition engineer. Participant 9 (CEO at NFDC) stated:

> In what way would this work? The role of the demolition industry is always neglected when it comes to discussing the circular economy. We are never involved. Designers are leading this process without consulting us. We are the experts in our field, and we inherently know what things are recycled, how they are recycled, and how to reuse them again. Transitioning towards circular built environment will never thrive without involving all parties in the construction cycle.

Few participants elaborated on the fact that the role of the demolition industry is often neglected, and two factors were elicited. Firstly, demolition is considered to be separated from other phases of the construction cycle. There is minimal engagement between demolition contractors and other construction professionals. Thus, many practitioners outside demolition do not have sufficient understanding of what demolition is, what it involves, and what demolition contractors are capable of. One of the participants mentioned as a result, that a demolition contractor is not perceived as a true engineer by other construction professionals, and therefore his role is belittled. And secondly, one of the major reasons why demolition input is minimal in the movement towards the circular economy is due to lack of researchers and lack of academic qualifications in the industry. Participant 11 (client) mentioned:

> Demolition is generally formed of rough builders and research and development is not a priority for many. And, due to the harsh nature of demolition, researchers tend to keep away and would rather contribute their research input to different sectors.

This study however shows that the demolition industry with its profound experience is able to contribute to the movement towards the circular economy. EDCI implementation entails many benefits to the movement towards the circular economy. Firstly, the demolition contractor through experience, knows what is difficult to deconstruct and what is not. Their advice to designers on the choices of materials is invaluable. This will therefore stimulate clients and designers to begin designing buildings for deconstruction; ensuring that the long-term use of materials will be increasingly specified as to be retrieved and reused, thus engendering a closed-loop concept. Subsequently, the demolition contractor will help developing a deconstruction methodology with details containing the best method to deconstruct the building, what materials are reusable, what requires recycling, best access to site, and what risks are involved. This process will reduce the uncertainty a demolition contractor usually encounters on site, as all details about the project are highlighted within the deconstruction methodology. Finally, collaborative working by increased engagement with demolition contractors and the wider design team improves understanding and appreciation of roles and responsibilities and associated expertise. This would result in a growing mutual respect between construction parties.

The implementation of EDCI however, faces challenges. The biggest challenge envisaged to implementing the process is time; as most buildings take many years to be demolished, many things within the industry would have changed by the time the building reaches its end-of-life, thus the deconstruction methodology might not be valid any longer. Additionally, bringing an entire industry to the equation requires a change in practice, and the construction industry inherently resists any change that might occur to its practices (Lines *et al.,* 2015). Furthermore, all the interviewees agreed on two main points, which were similar to ECI challenges: (1) the change begins by clients, and clients unless there are financial incentives involved, will not be willing to incur further expenditure for the expertise of the demolition contractor, and (2) the fear of potential clash between the involved parties. Additionally, the challenge of whether the demolition contractor, if willing to provide advice, would he be listened to? As mentioned before, a demolition contractor is not perceived as an engineer due to lack of academic qualification, and due to lack of understanding from other construction parties of what demolition involve. Thus, many of the interviewees alluded that they will only be overruled by designers, as the expertise of the demolition contractor is undervalued by other construction professionals.

Despite the aforementioned, many of the suggested challenges are similar to ECI challenges, and could be tackled through trust, transparency, and collaboration (Bundgaard *et al.,* 2011). If the involved parties commit towards achieving one desired aim, whilst adhering to mutual respect, most of the specified challenges would not be a threat to the implementation of EDCI. Thus, the benefits of EDCI implementation outweigh the challenges.

The question of how to get EDCI actioned was difficult for the participants to answer. Many suggested stringent legislations to enforce the change; this is seen as the ideal method to convince clients to take on further expenditure (Akinade *et al.,* 2017). However, few participants asserted that the optimum method would be through creating successful case studies for the industry through collaboration. The representative organisations of the demolition industry alongside the representative organisations of design and construction to take the initiative and agree on mutual terms, aims and objectives to invest in developing sustainable solutions for the industry. The outcome of such collaboration will establish successful case studies for the industry and will culminate in lessons learnt that will act as guidelines for major organisations who might be willing to take the initiative to apply processes similar to EDCI.

This paper proposes to begin perceiving demolition as the beginning of life rather than the end of life phase of the construction cycle. This applies specifically for large demolition contractors, as once buildings are demolished, a new construction site is built. Therefore, demolition is considered to be phase 1 of the work, and this would facilitate the engagement of demolition within the construction cycle; thus, facilitating the implementation of EDCI.

CONCLUSIONS

The aim of this paper was to investigate the role of the demolition industry in the movement towards the circular economy through exploring the benefits and challenges of involving a demolition contractor at the design stage of construction. Through conducting 12 in-depth interviews with different construction practitioners who have sufficient understanding of both construction and demolition, a new concept has been introduced which is early demolition contractor involvement (EDCI). The

concept was inspired by early contractor involvement (ECI) contracting method. EDCI seeks to engage a demolition contractor at the design stage to benefit the design process from the expertise and knowledge of demolition with decisions concerning the end-of-life phase. Ten benefits and ten challenges have been identified as a result of the interviews. Findings show that through EDCI, the demolition industry have a vital role in the movement towards the circular economy. Firstly, A demolition contractor through experience, knows what is recyclable and what is not. Their advice to designers on the choices of materials is invaluable. This will stimulate clients and designers to design for deconstruction; ensuring that the long-term use of materials will be increasingly specified as to be retrieved and reused, thus engendering a closed-loop concept. Additionally, the demolition contractor will ensure that end-of-life factors are considered at early phases of design through developing a deconstruction plan for future demolition, improved risk assessment, and contribute to planning applications concerning end-of-life phase. Conversely, findings show that time, extra cost on clients, and adversarial relationships are expected to occur as a result of EDCI implementation. The benefits of implementing EDCI however, outweigh the challenges, because most of the identified challenges are a replica of ECI challenges, which have been dealt with in previous projects that implemented ECI. This study is limited to demolition expert's perspective without involving designers in the process. Future studies regarding this subject should therefore involve designers' perspectives of EDCI implementation and their perceived benefits and challenges of the process.

REFERENCES

Akinade, O O, Oyedele, L O, Omoteso, K, Ajayi, S O, Bilal, M, Owolabi, H A, Alaka, H A, Ayris, L and Looney, J H (2017) BIM-based deconstruction tool: Towards essential functionalities, *International Journal of Sustainable Built Environment*, 6(**1**), 260-271.

Arditi, D, Elhassan, A and Toklu, Y C (2002) Constructability analysis in the design firm, *Journal of Construction Engineering and Management*, 128(**2**).

Lemmens, C and Luebkeman, C (2016) *The Circular Economy in the Built Environment*. London: Arup.

Boon, K S (2015) Early contractor's involvement a paradigm shift in procurement approach, *In: The 19th Pacific Association of Quantity Surveyors Congress*, 28 May - 1 June, Yokohama, Japan, 1-11.

Braun, V and Clarke, V (2006) Using thematic analysis in psychology qualitative, *Research in Psychology*, 3, 77-101.

Bundgaard, K, Klazinga, D and Visser, M (2011) *Traditional Procurement Methods Are Broken: Can Early Contractor Involvement Be the Cure*? Available from https://www2.iadc-dredging.com/article/traditional-procurement-methods [Accessed 10/07/2019].

Cheshire, D (2016) *Building Revolutions - Applying the Circular Economy to the Built Environment*. London: RIBA Publishing.

Creswell, J W and Clark, V L P (2011) *Designing and Conducting Mixed-Methods Research*. London: Sage Publications.

Guest, G, MacQueen, K and Namey, E (2014) *Applied Thematic Analysis*. London: Sage Publications.

Guy, B and Shell, S (2002) Design for deconstruction and materials reuse *In*:

Proceedings of the CIB Task Group 39 - Deconstruction Meeting, 9 April, Karlsruhe, Germany.

Joyce, R (2015) Construction (Design and Management) regulations 2015. *In: CDM Regulations 2015 Explained*. London: Institution of Civil Engineers.

Laryea, S and Watermeyer, R (2015) Early contractor involvement in framework contracts, *Proceedings of the Institution of Civil Engineers*, *Management, Procurement and Law*, 169(**1**), 4-16.

Leising, E, Quist, J and Bocken, N (2018) Circular economy in the building sector: Three cases and a collaboration tool. *Journal of Cleaner Production*, 176, 976-989.

Lines, B C, Sullivan, K T, Smithwick, J B and Mischung, J (2015) Overcoming resistance to change in engineering and construction: Change management factors for owner organizations, *International Journal of Project Management*, 33(**5**), 1170-1179.

Merriam, S B (1998) *Qualitative Research and Case Study Applications in Education*. Jossey-Bass Publishers: San Francisco.

Mosey, D (2009) *Early Contractor Involvement in Building Procurement: Contracts, Partnering and Project Management*. Chichester, UK: Wiley-Blackwell.

Osaily, Y, Copping, A and Lo, S (2018) Critical success factors: The development of a conceptual framework for demolition projects. *In*: Gorse, C and Neilson, C J (Eds.), *Proceedings 34th Annual ARCOM Conference*, 3-5 September 2018, Queen's University, Belfast, UK. Association of Researchers in Construction Management, 209-218.

Patton, M Q (2002) *Qualitative Research and Evaluation Methods 3rd Edition*. London: Sage Publications, 598.

Rahman, M M and Alhassan, A (2012) A contractor's perception on early contractor involvement, *Built Environment Project and Asset Management*, 2(**2**), 217-233.

Sødal, A H, Laedre, O, Svalestuen, F and Lohne, J (2014) Early contractor involvement: Advantages and disadvantages for the design team. *In*: Proceedings Iglc-22, Oslo, Norway, 519-531.

Song, L, Mohamed, Y and AbouRizk, S M (2009) Early contractor involvement in design and its impact on construction schedule performance, *Journal of Management in Engineering*, 25(**1**), 12-20.

CONTRACTS AND PROCURMENT

READINESS ASSESSMENT OF PUBLIC-PRIVATE PARTNERSHIPS IMPLEMENTATION WITHIN TANZANIAN HOUSING PROJECTS: CHALLENGES, STRATEGIES AND APPROACHES

Neema Kavishe[1] and Nicholas Chileshe[2]

[1] *School of Architecture, Construction Economics and Management (SACEM), Ardhi University, Dar es Salaam, Tanzania*

[2] *Natural and Built Environments Research Centre (NBERC), School of Natural and Built Environment, University of South Australia, Adelaide, SA 5001, Australia*

Despite the advocated benefits of housing project public-private partnerships (PPPs) such as alleviating the housing problems within the developing countries, the PPPs implementation has yielded mixed results with a number of developing countries facing project management challenges, including high termination rates of PPPs projects. This clearly demonstrates a need for undertaking more PPP empirical studies around the readiness assessment for implementing PPPs. To address the identified knowledge gaps, this study which is underpinned by the theoretical lenses of innovation diffusion theory, seeks to assess and investigate issues around the Tanzanian practitioner's readiness for PPP adoption. This research is empirically informed from semi-structured interviews with ten public and private sector practitioners within the Tanzania housing sector. The standard qualitative technique of content analysis was used for the data as collected. The findings show that the main 4 challenges, which are nested within the structural, relational and cognitive issues affecting the readiness process as: (i) lack of awareness and usage of PPPs framework models during the feasibility and subsequent implementation process; (ii) limited knowledge and skills required for PPPs practitioners exacerbated by poor capacity building; (iii) lack of engagement of experts during the viability and assessment process; and (iv) poor selection process of private partners. The main readiness strategies and approaches were structured around the following: (i) timing and preparation for adoption of strategies; (ii) undertaking of feasibility studies; (iii) usage of PPP frameworks; (iv) utilisation of experts in the assessment process; (v) enhanced capacity building; and (vi) selection of private partners. The results of this study foster a better understanding of the readiness assessment strategies and approaches for successfully implementing PPPs in housing projects. Subsequently, this could lead to improved performance outcomes within a sector and economy acknowledged as having earlier PPPs project terminations.

Keywords: housing projects, innovation diffusion, PPP, readiness assessment

INTRODUCTION

Tanzania like many other emerging economies and African countries continue to lack better public services such as housing, water, schools, power supply, transportation,

[12] nicholas.chileshe@unisa.edu.au

Kavishe, N and Chileshe, N (2019) Readiness Assessment of Public-Private Partnerships Implementation Within Tanzanian Housing Projects: Challenges, Strategies and Approaches *In:* Gorse, C and Neilson, C J (Eds) *Proceedings of the 35th Annual ARCOM Conference,* 2-4 September 2019, Leeds, UK, Association of Researchers in Construction Management, 345-354.

waste management to mention a few. In order to improve the delivery of these services and facilitate creative and innovative approaches, Public Private Partnership (P3) is considered a practical alternative. In that context, Tanzanian Government adopted the P3 strategy to address the current situation (NHC, 2010; Kidata, 2013). However, despite the adoption of P3 in various sectors of the Tanzanian economy the prevailing problems remain unresolved. This obviously shows the presence of difficulties delaying the success of such services despite the Government's wish to collaborate with the private sector in addressing the infrastructural problem in the country (Kavishe and An, 2016). The situation has been worsening in urban regions where there is high population growth (NHC 2010). Consequently, the supply of housing in Tanzania is failing to keep up with the urban growth trend. Likewise, the 2012 census report showed that the Tanzanian population has tripled since 1967 and is continuing to increase. To mitigate the population growth and subsequent consequences of shortage of housing, the Tanzanian government like most in the emerging economies has been stimulated to adopt the popular P3 strategy as solution to delivering housing projects. However, P3s are more complex than traditional procurement process (World Bank 2016). As a result, P3s require a vast amount of preparation, training and experience as well as good monitoring and management skills. Moreover, from the review of studies undertaken it is very evident that there are limited studies undertaken in the Sub-Saharan Africa aimed at exploring the readiness assessment for P3s implementation. Thus, to narrow this knowledge gap, the study aims to assess and investigate issues around the Tanzanian practitioner's readiness for P3 adoption.

LITERATURE REVIEW

To facilitate the assessment of readiness for P3 and the exploration of issues around the readiness assessment of P3s within the Tanzanian housing projects context, the concepts of "readiness" and "innovation" needs to be defined. According to Bernerth (2004), readiness is defined as: "a condition of the mind when reproducing willingness or interest to altering the way an individual think or does things" (Bernerth, 2004, pg.39). Similarly, Al-Shareem *et al.,* (2013) and Al-Shareem *et al.,* (2015) described the readiness index as an indicator for measuring the extent of preparedness towards new knowledge. The study by Al-Shareem *et al.,* (2015, pg. 57) in citing Burns and Stalker (1961) and Vakola (2013) further defined readiness as: "Pertaining to the ability or capability of an organization to adopt or implement new ideas, processes or products". These two studies by Al-Shareem *et al.,* (2013) and Al-Shareem *et al.,* (2015) used two main dimensions: drivers (optimism and innovativeness) and barriers (discomfort and security). Optimism and innovativeness were taken to mean factors contributing towards the preparedness/readiness while discomfort and security means factors hindering the readiness. Al-Shareem *et al.,* (2015) demonstrated that there is an interrelationship between the external factors (market readiness, government policies and environmental uncertainty) and the degrees of readiness. Chan *et al.,* 2010 study have also confirmed these results by demonstrating the significance of these three aspects on P3.

The concept of "readiness" is also aligned and underpinned by the application of "Innovation Diffusion Theory". For example, the seminal study of Stock (1997) defined the concept of "Diffusion of Innovation" as the process by which something which is "new" moves from one area, person or location to another. Likewise, Mahajan and Peterson (1985 cited in Hosseini *et al.,* 2015, pg. 154) defined innovation as "Any idea, object, or practice that is perceived as new by members of

the social system". Using the above definitions, it is evident that P3s falls into this category as something "new" or still in infancy stage as highlighted by the World Bank (2016) which moves from the developed economies and well established P3s markets such as Australia to a different location, namely Tanzania and among members of the social systems such as Tanzanian private and public PPP stakeholders. The second qualifier of P3s as an "innovative process" within the Tanzanian context is premised on meeting one of the criteria of the seven attributes or phenomenon complying with the attributes of innovations described by Hosseini *et al.,* (2015) as "New to the institution implementing the innovation". The above assertion by the World Bank (2016) regarding P3s in Tanzania further validates and reinforces the definition. Using the same principles, and drawing upon approaches from anthropology and sociology, the P3s and associated "readiness" can be understood as a special environment where new market capabilities and routines can potentially be created. Recent studies such as Hosseini *et al.,* (2018) have applied the innovation diffusion theory (IDT) in their quest to integrate sustainability on construction mega projects (deemed a new phenomenon) within a lesser studied context such as Iran.

Therefore, drawing upon the review of the definitions as provided, the readiness assessment undertaken within the context of our study implied the ability or capability of the Tanzanian practitioners (both public and private) to adopt or implement P3s which could be inferred as new ideas. The processes or products inherent with the definition was probed from the perspective of whether the Tanzanian practitioners had any existing P3 frameworks prior to starting up their PPP projects, or whether they had a system to engage transaction advisers/solicited the expertise of others to assess their viability of their P3 housing delivery projects as well the readiness of the employees through undertaking P3 courses and training to improve their knowledge and skills, as well as being in a position to adopt the necessary strategies. The approach as undertaken was also mapped to the following five stages associated with the spread of innovation: knowledge, persuasion, decision, implementation, and confirmation (Newell, 2001). The first stage involves attaining knowledge and revelation to the innovation. The second stage, persuasion, refers to the creating of favourable attitudes and beliefs concerning the innovation in response to knowledge obtained in the first stage. The third, decision, the individual/members decide to accept or reject the innovation. The fourth, implementation, an innovation is executed. Finally, the confirmation stage includes searching for the reinforcement of the decision made.

The adoption of P3s within the Tanzanian construction industry and particularly the housing sector is still relatively in its infancy stage. This is not withstanding the fact that one of the prominent Tanzanian public sector organisations, the National Housing Cooperation (NHC) has adopted PPPs as an alternative housing delivery strategy since the 1980s and 1990s in form of Joint ventures (JVs) prior to the formulation of P3 policies, guidelines and the Acts. However, despite the efforts in enacting the JVs, according to the World Bank (2016, pg. 26), Tanzania's infrastructure is still worse than neighboring Southern Africa Development Community (SADC) countries such as Zambia's and Uganda's and substantially worse than Kenya's and Rwanda's in terms of its impact on competiveness.

The main contributing challenges have been the lack of adequate P3 legal framework to guide the implementation of such projects and insufficient skills and knowledge in planning, procurement and management of P3 projects (Ibid). Kavishe and An (2016) identified 19 major challenges hindering housing PPPs in Tanzania whereby the top

three ranked were related to project management as follows: inadequate P3s skills and knowledge leading to poor planning and application; poor P3s contract and tender documents; and inadequate project management and monitoring by public sector. Therefore, from the literature individual countries have different perceptions around the best practices associated with the readiness assessment for implementing P3s in affordable housing scheme (AHS) projects. In addition, given the high termination rates of P3 projects in Tanzania (World Bank, 2016); there is clearly a need for undertaking more PPP empirical studies around the readiness assessment for implementing P3s in AHS projects. Therefore, in response to the identified knowledge gaps, this study seeks to assess and investigate issues and coping strategies around the Tanzanian practitioner's readiness for PPP adoption.

According the studies by Rogers (2002, 2004), the Diffusion of Innovation Theory seeks to explain how novel ideas, products and practices are adopted by members of a specific social group. Meaning that, diffusion process occurs when innovation is accepted and adopted by members of a certain community. Accordingly, there are four stages that should be followed for the adoption of innovation: 1) Awareness, 2) Decision to adopt (or reject); 3) Initial use; and 4) Continued use. Likewise, Rogers (2003) proposed and identified the following four main elements of IDT: innovation, communication channel, time, and social system. Therefore, our present study used this theory to aid and conceptualise the change processes when new technologies or P3s to be more precise are adopted and diffused through Tanzanian public and private sector organisations. Many researchers from various disciplines such as public health, political science, history; economics, technology, and education have employed the IDT in the area of technology diffusion and adoption (Sahin, 2006). However, there are limited studies in the construction industry and specifically the housing sector that have been conducted empirically using innovation diffusion studies. With the exception of Hosseini *et al.,* (2018) study which proposed an integrated conceptual model in order to highlight the major aspects of diffusion of innovations in the architecture, engineering and construction (AEC) context, the theory has also been applied in a recent similar study (Kavishe and Chileshe, 2018).

RESEARCH METHODOLOGY

This study adopted a qualitative data collection approach whereby semi structured interviews were chosen mainly because it facilitates to produce rich information. The target population were all the PPP experts and stakeholders involved in PPP housing projects in Tanzania. But based on the infancy of PPP in Tanzania as highlighted by the World Bank, (2016) only10 semi-structured interviews were undertaken. The sample size is considered adequate, because the threshold of between 5-50 interviews is considered enough to reaching saturation (Patton, 2002). Similar studies such as Osei-Kei and Chan (2018) had a sample size of 10 interviewees. Therefore, a criterion-based approach was used in the selection of the interviewees as suggested by Maxwell (2005 cited in Liu and Wilkinson, 2011). The key criterion used included been a public partner or private partner to the housing P3 projects. The questions were prepared following the guidance as suggested by Qu and Dumay (2011) and were designed to assess and investigate issues around the Tanzanian practitioner's readiness for P3 adoption.The questions were further conceptualized using Roger's Diffusion of Innovation Theory (Rogers, 2002, 2004) where they were mapped to the following four stages of innovation: 1) Awareness; 2) Decision to adopt (or reject); 3) Initial use; and 4) Continued use. The duration of the interviews was between approximately 45 -100 minutes. Data was analysed through content analysis whereby;

patterns and themes were derived by identifying them as they appeared in the interview scripts. Profile of the interviewees is depicted in Table 1. It is observable that 80% of Interviewees hold top/senior positions in their organizations and participated in PPP housing projects hence prove the validity of the data collected.

Table 1: Profile of Interviewees -Individual characteristics

Interviewee	Designation of respondents	Experience in current position	Educational level	practice PPPHP	Current Status
A	Managing director	11~15years	Master's degree	Yes	Public Partner
B	Senior Legal officer	< 5 years (4yrs)	Master's degree	Yes	Public Partner
C	Assist. Legal officer	< 5 years (1yr)	Master's degree	Yes	Public Partner
D	CEO	11~15yrs (12yrs)	Master's degree	Yes	Private Partner
E	Project manager	>5 years (20yrs)	Master's degree	Yes	Public Partner
F	PPP clerk of works	> 15 years	Master's degree	Yes	Consultant
G	Managing director	> 15 years	PhD	Yes	Private Partner
H	Project manager	> 15 years	Master's degree	Yes	Public Partner
I	Associate Professor	>15 years	Ass. Professor	No	Researcher
J	Acting Director	6-10 years	Master's degree	No	PPP Advisor

RESULTS AND DISCUSSION

Based on the conceptualisation of the definition of "readiness", interviewees were asked questions around the timing and preparation for adoption of strategies, undertaking of feasibility studies, usage of P3 frameworks, utilisation of experts in the assessment process, capacity building through training of key personnel, and selection process of private partners. Most importantly, the readiness assessment is informed by the Tanzanian practitioner's knowledge of the P3 processes.

(a) *Timing and Preparation for Adoption of Strategies*: Rogers (2003) proposed and identified 'time' as one of the four main elements of IDT. Accordingly, from the innovation perspective, the 'timing' decision as when to start the P3 process is crucial to the success of that process. Interviewees A, B, E, F, and I acknowledged not having any form of advance preparations such as training for P3. This finding is hardly surprisingly due to P3s being relatively new phenomenon in Tanzania (World Bank, 2016). The inference and implication to be drawn from this lack of awareness is manifested in Roger's IDT (Rogers, 2002, 2004) which states that the 'knowledge' stage of the innovation is usually influenced by the characteristics of user (namely the Tanzanian public and private stakeholders), and characteristics of social systems.

(b) *Undertaking of Feasibility Studies*: Jamali (2004) study drew a number of lessons around P3 success and failure mechanisms and suggested that P3s must begin with careful groundwork and preparation, including a comprehensive feasibility study and economic evaluation for each potential partnership project. Based on findings, the majority (80%) of the interviewees did not undertake any form of feasibility studies, with the only exceptions being Interviewees D and J. For example, Interviewee J used the P3 coordinating unit function by giving it authority (power) to advise the public sector on the viability of the P3 project as well as examination of requests for proposals. Other strategies employed by Interviewee G included the development of procedures and guidelines for all matters in P3. The approaches and strategies undertaken by Interviewee G are also consistent with P3 literature on CSFs within developing and developed economies, as well as the need for undertaking feasibility studies (Ismail, 2013; Kwofie *et al.,* 2016)

In contrast, some of the public partners also failed to undertake the feasibility study for a number of reasons. For example, Interviewee A stated that, "The needs were

obvious, and they had to redevelop all dilapidated properties in order to safeguard them and increase organization revenue". Therefore, the responsibility for the feasibility study was entirely left to the private partner this was confirmed by Interviewees B, C, E, and H. Likewise, Interviewee G (private partner) acknowledged not undertaking the feasibility process and stated that:

> but the land allocation was very prime therefore we were quite sure that building high income residential apartment for foreigners working and living in Tanzania will give us high return on the project

The motivation of profits or high returns on the projects as expressed by Interviewee G is common practice among private partners.

(c) *Usage of PPP Frameworks*: The interviewees were asked whether they had any P3 framework models when starting up their P3 projects. Interestingly, an overwhelming majority (100%) indicated not using any formalised P3 frameworks. In contrast, they confirmed using their customised framework processes of carrying out the Joint Venture and P3 projects. This lack of awareness of existing P3 frameworks could be a recipe for failure in implementing the P3 projects. However, considering that many P3 frameworks and guides have been developed around the globe to help improve the outcomes of P3 projects (Almarri and Abuhijeh, 2017, pg. 170), this finding is further indication of the Tanzanian P3 private and public stakeholders as being in the 'persuasion' stage of adoption process given their usage of customized P3 frameworks. The lack of usage of frameworks among the interviewees could further be attributed to the Tanzanian regulatory framework not explicitly requiring the assessment and prioritization of PPPs within the broader context of public investment planning (World Bank, 20115, 43). Housing equally falls under public investment.

(d) *Utilisation of Experts in the Assessment Process*: The interviewees were asked whether they had a group of experts to assess the viability of the P3 projects. Majority (100%) indicated not using any experts. Meaning that, a system to engage transaction advisers was not in place. The findings around the decision by the Tanzanian private and public sector stakeholders or interviewees not to use experts in the assessment process is also consistent with literature on P3 implementation and Project Management (PM) challenges facing developing countries (Rwelamila, 2012; World Bank, 2016; Kavishe *et al.,* 2018; Osei-Kyei *et al.,* 2018). For example, the recent study by Osei-Kyei *et al.,* (2018) recommended the engagement of highly skilled and experienced external advisors to assist in the evaluation and assessment of proposals. Likewise, Rwelamila (2012, pg. 341) study of PM performance in the following selected developing countries comprising Botswana, Indonesia and Nigeria also found a lack of sufficient numbers of experts to support the planning, design and implementation of construction projects. However, the plausible explanation for the lack of engagement of P3 experts in this study could be associated with the lack of system to engage transaction advisers, P3 being relatively new in Tanzania, and hence the skills base might be lacking (Kavishe *et al.,* 2018; World Bank, 2016).

(e) *Capacity Building*: According to Luiz (2010), delivery of infrastructure projects in Africa requires the capacity to deliver massive, complex projects in an efficient manner. The same study acknowledged that African states did not possess this level of capacity although innovative public-private partnerships offered an avenue for such delivery through global cooperation. Likewise, capacity building and training have been acknowledged to enhance local practitioners' skills and knowledge in delivering P3 projects (World Bank, 2016; Osei-Kyei and Chan, 2018, pg. 18). From the IDT perspective, it is argued that to sustain the culture for innovation, firms should

emphasise the issue of human capital (Panuwatwanich *et al.,* 2009). Therefore, in order to ascertain the Tanzanian practitioners' readiness through capacity building by training of key personnel, it was revealed that the majority (100%) indicated not having staff with the pre-requisite skills or undertaken any formal training on P3.

For example, Interviewee A indicated that, at the beginning of the P3 implementation process, they only had 3 people within the National Housing Corporation who had a rough idea of partnering with private investors, whereas only 1 person had learnt about the process indirectly having attended a short course in the US. Similarly, Interviewee G stated that their organisation was heavily reliant on the NHC joint venture policy for guidance. The observations and findings from the interviewee responses are also consistent with the challenges around the training of manpower or human resources management issues in developing countries, as well as skills around P3s (Ismail, 2013; Kwofie *et al.,* 2016). For example, Osei-Kyei *et al.,* (2018), highlighted that, employment of highly skilled and competent staff during evaluations of proposals is among the strategies for effective management of unsolicited proposals for P3 implementation. Similarly, as noted by Kavishe *et al.,* (2018), as part of the capacity building, the identified PPP training should be preceded by assessing levels of P3 knowledge-base and skills in order to recognize their awareness level and tailor-made the course as appropriate.

(f) *Selection of Private Partners*: The last part was the evaluation around the selection of private partners. The basis of evaluation has also been identified as a key concern of procurement (Ruparathna and Hewage, 2015). Therefore, interviewees were asked how they selected their private partners with probing questions around whether it was through competitive selection, single source, and dependent on the selected option, the justification for that approach was sought. The findings revealed some mixed results ranging from opening tendering (Interviewee A); unsolicited proposals (Interviewees B, E, H and F), no selection procedures (Interviewees D, G, I and J) to non-competitive selection (Interviewees C and F). However, the above findings are consistency with literature on the enablers or CSFs around PPP implementation and procurement aspects (Chan *et al.,* 2010; Wibowo and Alfen, 2015; World Bank, 2016). For example, the comparative study of the UK and Hong Kong by Chan *et al.,* (2010) identified competitive procurement process (enough bidders in the process), and transparency procurement process among the CSFs for P3s implementation.

Additionally, there was evidence of non-competitive selection as Interviewee C stated that it was merely on first come, first serve basis, whereas Interviewee F commented this was a non-competitive selection because it was an unsolicited proposal meaning that the private partner sold out the idea to the public sector and eventually became partners. The pattern was the same with some evidence of open tendering of proposals. For example, Interviewee A observed that:

> Partners were not officially selected. Instead a list of projects was drawn out and interested investors or developers would come and pick the projects they would wish to develop and then will prepare their proposals

Similarly, Interviewee B expressed the same sentiments and noted that, "partners came in themselves to select the plots they were interested to develop, then after making a choice, they brought in their development proposal to be assessed. The inference from the above findings is that, as part of the readiness process, selection of private partners must be given due consideration.

CONCLUSIONS AND RECOMMENDATIONS

In order to gain insights into the Tanzanian practitioner's readiness for change in implementing the P3s within the housing projects delivery, a qualitative approach comprising semi-structured interviews was adopted. The readiness assessment highlighted a number of challenges including; a lack of awareness and usage of P3 framework models during the feasibility and subsequent implementation process; limited knowledge and skills required for P3 practitioners exacerbated by poor capacity building; lack of engagement of experts during the viability and assessment process, and poor selection process of private partners giving rising to unsuccessful projects. These main challenges were further established to be nested within the structural, relational and cognitive issues affecting the readiness process. In terms of the readiness strategies and approaches, the following six were identified: (i) timing and preparation for adoption of strategies; (ii) undertaking of feasibility studies; (iii) usage of PPP frameworks; (iv) utilisation of experts in the assessment process; (v) enhanced capacity building; and (vi) selection of private partners. Additionally, the findings of the study further confirmed the assertions of the Roger's Diffusion of Innovation Theory (Rogers, 2002, 2004) regarding the limited P3 knowledge exhibited by the Tanzanian practitioners. This also highlighted the state and characteristics of the Tanzanian public and private sector users and social systems as being in the infancy stage (World Bank, 2016) as the main overarching reasons for the lack of knowledge around P3 processes.

A number of important implications for P3 practitioners, policy makers, and government are suggested. For practitioners, by understanding and identifying the readiness assessment strategies and approaches, both the Tanzanian private and public sectors P3 practitioners would be supported in successfully implementing P3s in housing projects. For government and policy makers, the undertaking of the 'readiness assessment' would enable and provide them with an opportunity for the development of appropriate strategies and coping mechanism specifically conducive for the Tanzanian environment. Secondly, this 'readiness assessment' would inform the formulation of policy guidelines for effective management of unsolicited P3 proposals. Thirdly, the results of this study further foster a better understanding of the readiness assessment strategies and approaches for successfully implementing P3 in housing projects. Subsequently, this could lead to improved performance outcomes within a sector and economy acknowledged as having earlier P3 project terminations. Finally, the findings would provide both the government and practitioners with policy directions and best practice associated with encouraging the diffusion of innovation as suggested by the Rogers Diffusion of Innovation Theory. The main limitation of the study was around the lack of generalization as the interviewees consisted of stakeholders drawn from only one city in Tanzania, namely Dar-es-Salaam. Future studies should be extended to other parts of Tanzania.

REFERENCES

Almarri, K and Abuhijleh, B (2017) A qualitative study for developing a framework for implementing public-private partnerships in developing countries, *Journal of Facilities Management*, 15(**2**), 170-189.

Al-shareem, K M, Roosli, R B and Yusof, N A (2013) Readiness to adopt public-private partnership (PPP) in housing development in Yemen, *In*: *International Conference on Business Innovation, Entrepreneurship and Engineering*, December, Penang, Malaysia, 67-70.

Al-Shareem, K M, Yusof, N A and Kamal, E M (2015), External factors influencing the readiness for implementing public-private partnerships among public and private organizations in Yemen, *Journal of Science and Technology Policy Management*, 6(**1**), 56-75.

Bernerth, J (2004) Expanding our understanding of the change message, *Human Resource Development Review*, 3(**1**), 36-52.

Chan, A P, Yeung, J F, Calvin, C, Wang, S Q and Ke, Y (2010) Empirical study of risk assessment and allocation of public-private partnership projects in China, *Journal of Management in Engineering*, 27(**3**), 136-148.

Hosseini, M R, Chileshe, N Zuo, J and Baroudi, B (2015), Adopting global virtual engineering teams in AEC Projects: A qualitative meta-analysis of innovation diffusion studies, *Construction Innovation*, 15(**2**), 151-179.

Hosseini, M R, Banihashemi, S, Martek, I, Golizadeh, H and Ghodoosi, F (2018), Sustainable delivery of megaprojects in Iran: Integrated model of contextual factors, *Journal of Management in Engineering*, 34(**2**), 05017011-1.

Ismail, S (2013) Critical success factors of public private partnership (PPP) implementation in Malaysia, *Asia-Pacific Journal of Business Administration*, 5(**1**), 6-19.

Jamali, D (2004) Success and failure mechanisms of public private partnerships (PPPs) in developing countries: Insights from the Lebanese context, *International Journal of Public Sector Managemen*t, 17(**5**), 414-430.

Kavishe, N and An, M (2016) Challenges for implementing Public Private partnership in housing projects in Dar es Salaam City, Tanzania *In:* Chan, P W and Neilson, C J (Eds.), *Proceedings of the 32nd Annual ARCOM Conference*, 5-7 September 2016, Manchester, UK, Association of Researchers in Construction Management, 2:931-940.

Kavishe, N, Jefferson, I and Chileshe, N (2018) An analysis of the delivery challenges influencing Public Private Partnership in housing projects: The case of Tanzania, *Engineering, Construction and Architectural Management*, 25(**2**), 202-240.

Kavishe, N and Chileshe, N (2018) Identifying project management practices and principles for public-private partnerships in housing projects: The case of Tanzania, *Sustainability*, 10(**12**), 1-23.

Kidata, A (2013) A brief of urbanization in Tanzania in Prime Minister's office regional administration and local government, 1 June 2013, *Resilient Cities Conferences*, Bonn.

Kwofie, T E, Afram, S and Botchway, E (2016) A critical success model for PPP public housing delivery in Ghana, *Built Environment Project and Asset Management*, 6(**1**), 58-73.

Liu, T and Wilkinson, S (2011) Adopting innovative procurement techniques: Obstacles and drivers for adopting Public Private Partnerships in New Zealand. *Construction Innovation*, 11(**4**), 452-469.

Luiz, J (2010), Infrastructure investment and its performance in Africa over the course of the twentieth century, *International Journal of Social Economics*, 37(**7**), 512 -536.

Morledge, R and Owen, K (1998), Critical success factors in PFI projects, *In:* W Hughes, (Ed.) *14th Annual ARCOM Conference*, 9-11 September 1998, University of Reading Association of Researchers in Construction Management 2, 565-574.

Newell, S (2001) Management fads and fashions, *Organization*, 8(**1**), 5-15.

NHC (2010) *The National Housing Corporation Strategic Plan for 2010/11- 2014/15*. Dar es Salaam: National Housing Corporation.

Osei-Kyei, R, Chan, A P C, Javed, A A and Ameyaw, E E (2017) Critical success criteria for public-private partnership projects: international experts' opinion, *International Journal of Strategic Property Management*, 21(**1**), 87-100.

Osei-Kyei, R and Chan, A P C (2018) Public sector's perspective on implementing Public-Private Partnership (PPP) policy in Ghana and Hong Kong, *Journal of Facilities Management*, 16(**2**), 175-196.

Osei-Kyei, R, Chan, A P C, Dansoh, A, Ofori-Kuragu, J K and Oppong, G D (2018), Strategies for effective management of unsolicited public-private partnerships proposal, *Journal of Management in Engineering*, 34(**3**), 113-123.

Panuwatwanich, K, Stewart, R A and Mohamed, S (2009), Validation of an empirical model for innovation diffusion in Australian design firms, *Construction Innovation*, 9(**4**), 449-46.

Qu, S Q and Dumay, J (2011) The qualitative research interview, *Qualitative Research in Accounting and Management*, 8(**3**), 238-264.

Rogers, E (2002) Diffusion of preventive innovations, *Addictive Behaviors*, 27(**6**), 989-93.

Rogers, E M (2003) *Diffusion of Innovations 5th Edition*. New York, NY: The Free Press.

Rogers, E (2004) A prospective and retrospective look at the diffusion model, *Journal of Health Communication*, 9(**1**), 13-19.

Ruparathna, R and Hewage, K (2015), Review of contemporary construction procurement practices, *Journal of Management in Engineering*, 3(**31**), 04014038.

Rwelamila, P D (2012) Construction project performance in developing countries, *In:* G Ofori, (Ed.) *Contemporary Issues in Construction in Developing Countries*, London: Spoon Press/Taylor and Francis, 318-346.

Sahin, I (2006) Detailed review of Rogers' diffusion of innovations theory and educational technology-related studies based on Rogers' theory, *Turkish Online Journal of Educational Technology*, 5(**2**), 14-23.

Stock, J R (1977) Applying theories from other disciplines to logistics, *International Journal of Physical Distribution and Logistics Management*, 27(**9/10**), 515-539.

Wibowo, A and Alfen, H W (2015) Government-led critical success factors in PPP infrastructure development, *Built Environment Project and Asset Management*, 5(**1**), 121-131.

World Bank (2016) Tanzania Economic Update: The Road Less Traveled, Unleashing Public Private Partnerships in Tanzania Africa Available from http://documents.worldbank.org/curated/en/302151467992051044/Tanzania-economic-update-the-road-less-traveled-unleashing-public-private-partnerships-in-Tanzania [Accessed 10 March 2018].

CHANGE AND CONTINUITY IN THE CHINESE CONSTRUCTION SECTOR: PRACTITIONER RESPONSES TO BIDDING AND TENDERING

Beibei Qin and Stuart Green[1]

School of Construction Management and Engineering, University of Reading, Chancellor's Building, Whiteknights, Reading RG6 6DF

Despite the phenomenal growth of the Chinese construction sector there is a notable absence of practice-based research relating to bidding and tendering. The broader context is provided by the introduction of marketization through a series of policy announcements dating back to the 1980s. A sensemaking perspective is adopted as a means of bridging between macro-level policy announcements and micro-processes of bidding and tendering. The selected case study is a large state-owned construction enterprise in the Chongqing city region in South West China. A mixed-methods approach includes semi-structured interviews with senior practitioners and documentary analysis. The findings illustrate how the introduction of bidding and tendering has resulted in a complex plethora of hybrid practices. The pace of change is such that the construction sector in the People's Republic of China is best understood in terms of continuous adjustment to an ever-changing landscape. Hence it requires research approaches which privilege change over stability.

Keywords: bidding, China, contracting, marketization, sensemaking

INTRODUCTION

Since the foundation of the People's Republic of China (PRC) in October 1949, the Chinese construction sector has experienced a series of significant transitions. The announcement of the Open Door strategy by the Chinese government in 1978 was an especially important turning point in the transition from a centrally-planned economy towards the espoused 'social market'. China more generally has experienced unprecedented levels of economic growth accompanied by extensive urbanization. It is within this context that central government has issued a series of policies relating to the construction sector, including both contractors and professional services. Of particular importance is the advocated adoption of bidding and tendering as a means of invoking market competition. The aim of the described exploratory research is to provide insights into the way senior managers within contracting firms interpret and enact bidding and tendering. Strangely, the existing literature relating to the Chinese construction sector accords little in the way of agency to practising managers. There is also a pronounced lack of emphasis on the macro processes through which bidding and tendering have been promoted through policy. The described research adopts a sensemaking perspective to bridge between macro-level policy announcements and the micro-processes through which biding, and tendering is enacted.

[1] s.d.green@reading.ac.uk

Qin, B and Green, S (2019) Change and Continuity in the Chinese Construction Sector: Practitioner Responses to Bidding and Tendering *In:* Gorse, C and Neilson, C J (Eds) *Proceedings of the 35th Annual ARCOM Conference,* 2-4 September 2019, Leeds, UK, Association of Researchers in Construction Management, 355-364.

The paper commences with a summary of the changing policy landscape since 1949. It is argued that to understand the Chinese construction sector today it is necessary to understand the path it has travelled. Particular emphasis is given to the projectification of construction as an essential precondition for the introduction of market mechanisms such as bidding and tendering. This is followed by a critical review of the current research literature relating to the Chinese contracting sector. On the basis of this review the adopted sensemaking perspective is justified. The research method is then described prior to the presentation of the research results. Finally, the broader implications are discussed, and recommendations are made for further research.

Change and Transition: The Policy Landscape

The Legacy of the Soviet System

Any longitudinal analysis of the evolution of the Chinese construction sector has to begin in the immediate aftermath of the second phase of the Chinese Civil War (1945-1949). The Soviet Union was at the time perceived as the exemplar of a communist state. Hence the Chinese government sought to follow the Soviet Union's path of heavy industry development implemented through a series of 5-year plans. The prioritised industries of steel, coal, electricity and machine manufacturing collectively accounted for 58.2% of planned investment in the first 5-year plan approved in 1955.

Construction operations were at the time organised through the engineering divisions of the People's Liberation Army (PLA). Such divisions were populated by rural peasant conscripts under the direction of a cadre of politically-trained officers. Construction work was allocated by the Ministry of Construction Engineering on the basis of command-and-control. PLA divisions were routinely named after the type of work to which they were assigned. For example, the 10th Division for Railway Engineering would serve the needs of the railway sector. Each division typically provided welfare services such as schools, nurseries and hospitals.

The Great Leap Forward takes a stumble

The targets set out in the second five-year plan (1958-1962) reflected a growing confidence amongst Chinese policy makers. By 1958 private ownership had finally been completely abolished and the aim going forward was to transform the agrarian economy into a socialist society by means of rapid industrialisation. The Great Leap Forward is now widely recognised to have been ill-conceived in promoting too much change too quickly (Liu, 2018). Construction output notably declined and did not return to previous levels until 1970.

The failure of the Great Leap Forward led directly to the Cultural Revolution (1966-1976). The period was characterised by further economic disruption with the closure of many factories. Chaos prevailed until the political faction known as the Gang of Four were removed from power in October 1976 following the death of Chairman Mao. The economy which emerged from the chaos of the Cultural Revolution was grossly imbalanced and still reliant upon a militarised construction sector.

The Open Door Policy of Deng Xiaoping

The Third Plenary Session of the 11th Central Committee of the Communist Party of China in 1978 marked a radical departure from the era of the Cultural Revolution. The new strategy placed a strong emphasis on economic development with an associated openness to the West. Policy announcements by Deng Xiaoping in 1980 specifically re-positioned the construction sector as being of central importance to the

economy. Construction was no longer seen as a service operation in support of heavy industrial projects but was seen as an important mechanism of wealth generation in its own right. This policy shift led directly to the subsequent prolonged boom in urbanisation. All of a sudden, the construction sector was in the front line of policy. The reform agenda which followed was extensive and was characterised by the rapid introduction of a plethora of market mechanisms. This was re-engineering of the Chinese economy on a massive scale, the effects of which are still being worked through the system. The shift was justified in terms of the 'social market'. The espoused aim was the mobilisation of market mechanisms in the cause of socialism. The Open Door Policy resulted in economic targets gaining primacy over the expressed ideological goals of the Chinese Communist Party (CCP) (Child, 1996).

Construction sector reform

The Open Door policy resulted in the introduction of market-based terminology through a series of policy announcements. Reforms introduced by the Chinese State Council in 1984 also started to designate key roles which had not existed in the previous system of command-and-control. Of particular note is the emergence of engineering contractors as quasi-autonomous entities. The newly-created state-owned construction firms were formed from the PLA's 'engineering army'. Some of the newly-designated 'enterprises' were allocated to specific cities or regions, others were assigned to sectoral ministries within central government. Perhaps of most significance was the way soldiers of the PLA were unilaterally re-designated as construction workers.

Markets of course are dependent upon competition; but even more fundamentally they are reliant on quasi-independent entities which engage in competition. The policy discourse emphasised the importance of 'energising' state-owned construction enterprises to be more efficient. Phrases such as ‘output value’, ‘revenue’, ‘profit’ and ‘loss’ were progressively introduced into the lexicon of the construction sector. Of particular importance was the introduction of bidding and tendering practices as the essential means of competition, although it would be naïve to expect these to become operational overnight. Nevertheless, the direction of travel was clear. State-owned construction enterprises were expected to operate with a degree of autonomy in competing for contracts independently from the centralised mechanisms of allocation. But the precise arrangements varied significantly across different city regions. Even within specific cities, a myriad of hybrid processes emerged as part of a continuously evolving transition. Even more controversial than the creation of the state-owned enterprises was the acceptance by the China State Council in 1984 that some enterprises should be privately owned. Many Party members continued to argue that private ownership was in contradiction to Marxist doctrine. Others were concerned that state-owned firms would be less competitive than those in private ownership (Ahlstrom and Bruton, 2001). Statistical data on the number of privately-owned firms notably only appeared in 1995. It is easy to imagine the extent to which such issues were debated at length in the higher echelons of the CCP.

'Project way construction'

Concurrent with the above was the progressive shift towards the projectification of the Chinese construction sector, otherwise phrased as the normalisation of the 'project' as the essential unit of production. The notion of projectification as a process has of course long since been of interest to the so-called Scandinavian school of project management (Söderlund, 2004). More recently, interest has extended beyond the increased primacy of projects towards a broader interest in the cultural and discursive

processes by means of which the notion of projects is invoked (Packendorff and Lindgren, 2014). Of particular note within China is the way the policy discourse progressively promoted the terminology of 'projects'. The main official proponent of 'project way construction' was Qinglin Zhang, director of the Construction Management Department in the Ministry of Construction from 1984 to 1993. The essence of the policy was 'the adoption of the project as the essential unit of production for contracting firms, thereby creating an inner market of labour, material, equipment, capital and technology' (Zhang, 1992; p.2). This was indeed a decisive break from Soviet-style methods of resource allocation towards a reliance on market mechanisms such as bidding and tendering. 'Project management' was subsequently promoted by the Ministry of Construction as the preferred means of organising construction, although few details were offered in terms of how it was supposed to work.

The projectification of construction also had clear implications for the employment status of construction operatives. Under the previous Soviet-style system, the system of lifelong state support was referred to as the 'iron rice bowl'. However, the emerging reality was that the livelihoods of construction operatives became increasingly subject to the dynamics of market competition. Construction workers were exposed to unprecedented levels of change compressed into a relatively short period of time. The experienced realities of market competition can be equated directly with Toffler's (1971) notion of 'future shock'. Significant numbers of construction workers were suddenly deemed surplus to requirements as euphemisms such as 'reducing the burden' became commonplace. The recently designated state-owned construction enterprises were subject to extensive downsizing as they sought to make themselves competitive. Zou and Zhang (1999) report the extensive stripping out of non-production activities within 30 state-owned enterprises. In response to the challenge of making themselves more competitive, inherited in-house services such as schools, nurseries and hospitals were routinely outsourced to local government.

The widespread downsizing of construction enterprises marked the erosion of long-established expectations associated with the 'iron rice bowl'. Figures presented by Gao (1999) suggest that in 1997 alone 9.40 million workers were laid off across the Chinese economy at large. The declining levels of employees in contracting firms under different forms of ownership are illustrated in Figure 1. This was undoubtedly change on a massive scale.

The picture which emerges is clear, such that it is easy to envisage the 'future shock' experienced by construction workers who suddenly found themselves surplus to requirements. This would have been especially severe given that only a few years previously they had been classified as soldiers in the PLA. Managers were also faced with a significant shift in the behaviours that were expected of them and could likewise no longer take continued employment for granted.

Construction-Related Research Literature

Taking change seriously

Surprisingly, the above described processes of change are only occasionally cited in the research literature relating to the Chinese construction sector. Even more rarely are they central to the research questions being asked. Yan *et al.,* (2019) are typical in vaguely alluding to 'drastic change' in the Chinese construction sector while focusing on a research question which is essentially static. Their specific interest relates to how large Chinese construction companies have apparently turned to program management

techniques as a means of managing multiple projects. The described parameters of change include issues such as risk, construction techniques, complexity and shortened schedules. Strangely, there is no mention of the root-and-branch reorganisation of the sector as part of the espoused policy of marketisation. Yan et al.'s (2019) stated research aim of identifying critical success criteria as a means of achieving better performance would seem well-intentioned, but it notably fails to engage with the material and discursive practices of construction practitioners. The research does however implicitly legitimise the 'project' as the essential unit of production. Yan *et al.,* refer directly to President Xi Jinping's "Thought on Socialism with Chinese Characteristics for a New Era". They are therefore seemingly aware of the policy level recognition that unregulated market competition too easily sits in tension with social harmony. Many in the West would of course make similar arguments.

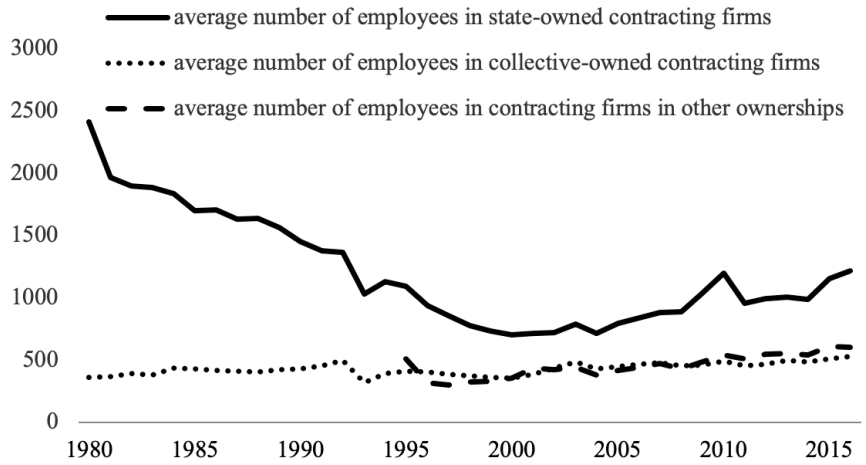


Figure 1 The average number of employees in contracting firms in different ownerships (Source: National Bureau of Statistics of China, 2016)

Recurring obsession with critical success factors

The methodology adopted by Yan *et al.,* (2019) is typical of many such studies. The pre-designed questionnaire notably requires the respondents to prioritise a list of issues derived from the literature. There is seemingly little interest in how practitioners might themselves describe the challenges with which they are faced. Of particular note is the assumption that the listed success factors continue to be valid over time despite the rapidly evolving landscape which they are claimed to represent. Neither is there any recognition of the know-how which is required to translate the identified critical success factors into feasible courses of action.

Lu *et al.,* (2008) similarly focus on critical success factors which supposedly contribute to the competitiveness of contractors. The methodology again relies on a questionnaire survey based upon a predetermined list of factors purportedly validated by means of a participative seminar. There is once again little recognition of the extent to which such factors might be overtaken by the rapid pace of change within the sector. The focus on competitiveness is self-evidently dependent upon the acceptance of market competition. Yet there is an apparent lack of recognition that markets ultimately comprise winners and losers. Paradoxically, the advocacy of critical success factors seems to imply that all firms within a given market can be in some way equally competitive.

The above two described studies of critical success factors are by no means isolated examples. Indeed, they are indicative of the most commonly adopted research

approach in respect of the Chinese construction sector. Different studies simply carve out slightly different issues to be factorised. For example, Zhao *et al.,* (2013) focus on critical success factors for enterprise risk management whereas Li *et al.,* (2009) consider competitiveness factors in the real estate market. In similar vein, Chan *et al.,* (2010) focus on critical success factors for public-private partnerships (PPPs) in infrastructure development.

There is much to be learned from the above-cited studies, not least in terms of the parameters within which the debate is conducted. But the extent to which the extracted factors are representative of a supposed external reality is at best questionable. The described processes of prioritisation are notably entirely dependent on the respondents ascribing the same meaning to the listed terms. Given that the terminology of the social market has only relatively recently been introduced, this would seem to be a significant assumption. There also seems to be a stark absence of qualitative research orientated towards accessing the interpretations of Chinese construction practitioners.

An alternative research approach would explore how different meanings are negotiated around the evolving terminology of the social market. Such an approach would ascribe a greater degree of agency to construction practitioners, thereby recognising that differing practices are likely to develop in different places in response to the same policy initiatives. The recent popularity of practice-based research approaches in the West would seem to have been neglected among those interested in the Chinese construction sector. At the very least, there is a need for a greater degree of methodological diversity.

METHODOLOGY

The Principles of Sensemaking

Sensemaking is concerned with the processes by which people seek to understand ambiguous, equivocal or confusing events (Colville *et al.,* 2012; Weick, 1995). In contrast to the studies described above, it focuses attention onto the processes of change from the perspective of the participants. The research aim is to understand how senior managers in Chinese contracting firms impose order on their day-to-day activities by applying patterns learned from their previous experience. Sensemaking notably privileges processes of change over stability. Such a perspective is conspicuously missing from the existing research literature relating to the Chinese construction sector. Of particular interest is the way practising managers make sense of the plethora of policy initiatives relating to the social market, and the roles which they create for themselves in its enactment. It is important to emphasise that sensemaking is not only about interpretation, it is also about taking action through ongoing processes of enactment and social interaction. Sensemaking is further held to be inseparable from issues of self-identity. Perhaps most importantly, sensemaking is seen to be a continuous activity through which individuals interact with the world around them. The combined focus on material and discursive practices positions sensemaking within the broad spectrum of practice-based research. Of particular note is the recognition that the micro processes of sensemaking frequently draw from macro-level scripts (Abolafia, 2010). To the authors' best knowledge, there is no previous study of bidding and tendering practice within the Chinese construction sector which draws from a sensemaking perspective.

Research method

The research comprised a case study of a construction enterprise operating within the Chongqing city region. Qualitative data was collected through a combination of semi-structured interviews and documentary analysis of company reports and available official statistics. This combination of methods enabled the researchers to judge the extent to which the interviewees offered plausible interpretations of key events derived from their previous experience. It was on this basis that the research method sought to bridge between macro-level processes of policy and the micro-processes of sensemaking. The aim was to understand sensemaking in flight rather than to access any sort of assumed static positivist reality. Sensemaking is in no small way concerned with the social construction of the localised realities within which practitioners operate. Abolafia (2010) argue that any failure to invoke broader institutionalised policy discourses would increase risk and reduce legitimacy. The latter is especially important within China given the regulating role of the CCP.

The selected construction enterprise, hereafter referred to as Yangtze Construction, is one of the largest state-owned contracting firms in the Chongqing city region. It was originally established in 1965 to serve the localised needs of the Chinese military. Yangtze Construction currently comprises 30 operating companies and in 2016 had a combined turnover of 16 billion yuan. The firm has experienced exponential growth since 2000, punctuated only by a period of relative stagnation from 2010-2013. It currently operates throughout China and has extensive overseas operations in countries such as Nigeria and Georgia.

The latest company report quotes the number of employees within Yangtze Construction as 5,000, having peaked previously at over 14,000 in 1988. The reduction in the number of employees despite the exponential growth in output is indicative of the extensive restructuring of state-owned enterprise as they strive to become more competitive. Interviews were conducted with 20 senior/middle managers including the General Manager, the Director of the Engineering Bureau and the Director of the Technology and Innovation Centre. Access was also gained to the Party secretaries with responsibility for specific operating companies. The questions were deliberately open-ended in order to ascertain the issues which the interviewees considered most important. However, the questions routinely encouraged them to identify what they considered to be the key events in shaping current practice. The description which follows focuses in particular on how practitioners seek to make sense of bidding and tendering.

EMPIRICAL FINDINGS

Loss of Control

The opening line of questioning related to the way the company secured work. The interviewees were seemingly accepting of the reality of operating within a market, and of the basic principles of market competition. Of particular note was the acceptance that the firm had to win work if they were to prosper. In the words of one interviewee: 'we have to take part in market competition; it is crucial'. Bidding and tendering were also widely accepted as the primary mechanisms of market competition. They were seen to apply not only to the appointment of the main contractor, but also to the appointment of sub-contractors. In both cases, the shift towards market competition was equated to a loss of control. In the words of one interviewee:

> We all have problems with his (the chairman of board) over-emphasis on 'control'. If the staff in charge of marketing are not valued by a contracting firm, who will go out to win projects? (Director of Marketing Bureau)

More fundamentally, there was a widespread implicit acceptance of the project as the essential unit of production. Interviewees would frequently refer to the Open Door policies of Deng Xiaoping. Most saw the introduction of market competition as having had a direct influence on the way construction enterprises are organised. They also often alluded to the loss of control which results from the introduction of market mechanisms. This was an especially recurrent theme when talking about the appointment of sub-contractors:

> The project manager previously had the right to choose sub-contractors and decide the price. They had too much autonomy. But now it is the market that decides how to distribute work, not the project manager. We introduced bid and tender. (Deputy General Manager).

Project managers have seemingly been forced to relinquish much of their personal control in respect of the appointment of sub-contractors. The interviewees seemed to be consistently searching for legitimate roles for themselves within the changing landscape. Such issues are notably ignored by the existing research literature.

Continued Importance of Guanxi

Notwithstanding the above, there were some interviewees who were resistant to the suggestion that bidding, and tendering comprises a radical shift in the way work is distributed. Several felt that it often comprises a bureaucratic process disconnected from any actual decision-making process. The culturally embedded system of social networks known as 'guanxi' was held to be the basis upon which managers strive to remain in control despite the introduction of market competition. Several interviewees suggested that clients often select a preferred contractor on the basis of guanxi, thereafter manipulating the tendering process to confirm the required outcome. Some referred to the need to 'run in the market', thereby implying some physical sense of having to go to different places to talk to different people in order to win projects. Activities such as collecting information, communicating with clients, inviting clients to visit construction sites and engaging in bidding and tendering processes were all described as falling within the remit of increasingly well-resourced 'marketing departments'. However, many of these activities are seemingly orientated towards preserving an 'inside track' with identified clients. Of particular interest is the suggestion that bidding, and tendering is a procedure which is commonly manipulated to confirm a pre-determined preference. Most firms in the West would also prefer to have an inside-track rather than being forced to engage in 'hard-ball' tendering.

Incomplete Project Information

Several interviewees referred to the advantages of privileged access to information in respect of tenders. Indeed, there was a broad consensus that the information provided at the time of tender is very often incomplete, thereby creating a necessity for clarification. The view was also expressed that clients use information as a means of ensuring that the preferred candidate is successful in the bidding process. In the words of one interviewee:

> We are still working on this project. Our guanxi helped us to get involved, but we are still discussing conditions. If the client favours you, they will give you more information. The chances of winning the bid then become bigger. (Party Secretary of engineering subsidiary).

Hence the key issue which determines the information provided is the extent to which the client favours the company. It should also be emphasised that tenders are not routinely awarded to the lowest bidder. Some clients were reported to be following a policy of awarding the project to the bid, which is closest to the average, while others award the project to the bid which is closest to the client's own in-house estimate. Both of these approaches are of course open to abuse. In the first case, the challenge for the contractor is to ascertain the value of the client's estimate. The contractor which is in possession of this most crucial piece of information is most likely to be successful. What tends to happen in these cases is that the client simply leaks the required information to the preferred bidder. In the second case, there is an opportunity for the pre-qualified contractors to engage in collusion to determine whose turn it is to be successful. On occasion, such collusion seemingly takes place with the tacit approval of the client. Such apparent abuses of competitive tendering should not necessarily be linked with corruption. Indeed, this was categorically not the impression gained. The pivotal issue seemed to be a fear of losing control to the 'hidden hand of the market'. Hence practitioners are prone to manipulating the outcome of the tendering process to secure preferred outcomes.

CONCLUSIONS

The qualitative findings presented above are persuasive in pointing towards an alternative research agenda which emphasises the way practitioners make sense of the changing landscape within which they operate. In methodological terms, the research has illustrated how sensemaking can be used as a means of bridging between macro-level policy announcements and micro-level practices. The interpretation of the structural realignment of the Chinese construction sector as a process of projectification is also held to be an original contribution. It therefore opens up new avenues of research which go beyond the current fixation with critical success factors. Practice-based research approaches such as that described cannot be conducted at a distance; they require detailed engagement with the worldviews of practitioners.

Despite the limitations of a single case study, the research has provided new insights into current practices associated with bidding and tendering. Of key importance is the recognition that the introduction of market mechanisms such as bidding and tendering routinely cause practitioners to rethink their roles and the way they interact with others. Bidding and tendering cannot be understood in isolation of the implementation of the social market and associated ongoing processes of projectification. It has further been suggested that bidding and tendering are routinely distorted by deeply-embedded practices of guanxi. Practitioners seemingly feel diminished by the apparent necessity to relinquish control to the marketplace. Hence bidding and tendering is often perceived as a bureaucratic process which lends itself to manipulation in the cause of reducing uncertainty. Further research is necessary, but there is little to suggest that such tendencies are necessarily corrupt. The practices portrayed are perhaps best described as pragmatic responses to the enactment of the social market. It must also be recognised that the legal and regulatory framework within China is still under development. The transition is therefore not only about the introduction of market mechanisms, it is also about the ways in which such mechanisms should be regulated.

REFERENCES

Abolafia, M Y (2010) Narrative construction as sensemaking: How a central bank thinks, *Organisation Studies*, 31(**3**), 349-367.

Ahlstrom, D and Bruton, G D (2001) Learning from successful local private firms in china: Establishing legitimacy, *Academy of Management Executive*, 15(**4**), 72-83.

Chan, A P, Lam, P T, Chan, D W, Cheung, E and Ke, Y (2010) Critical success factors for PPPs in infrastructure developments: Chinese perspective, *Journal of Construction Engineering and Management*, 136(**5**), 484-494.

Child, J (1996) *Management in China During the Age of Reform*. Cambridge: Cambridge University Press.

Colville, I, Brown, A D and Pye, A (2012) Simplexity: Sensemaking, organizing and storytelling for our time, *Human Relations*, 65(**1**), 5-15.

Gao, S (1999) Analysis of the employment situation in China and solutions, *Economist*, 4(**4**), 9-13 (in Chinese).

Li, H, Li, V, Skitmore, M, Wong, J K W and Cheng, E W (2009) Competitiveness factors: A study of the real estate market in China, *Construction Management and Economics*, 27(**6**), 567-579.

Liu, Q (2018) *The Second Five-Year Plan (1958-1962) The Great Leap Forward and Great Leap Backward*. Beijing: Chinese Communist Party (in Chinese).

Lu, W, Shen, L and Yam, M C H (2008) Critical success factors for competitiveness of contractors: China study, *Journal of Construction Engineering and Management*, 134(**12**), 972-982.

National Bureau of Statistics of China (2016) *Chinese Statistical Yearbook*. Beijing: NBSC.

Packendorff, J and Lindgren, M (2014) Projectification and its consequences: Narrow and broad conceptualisations, *South African Journal of Economic and Management Sciences*, 17(**1**), 7-21.

Söderlund, J (2004) On the broadening scope of the research on projects: A review and a model for analysis, *International Journal of Project Management*, 22(**8**), 655-667.

Toffler, A (1971) *Future Shock*. New York: Bantam.

Weick, K E (1995) *Sensemaking in Organizations*. Thousand Oaks, CA: Sage.

Yan, H, Elzarka, H, Gao, C, Zhang, F and Tang, W (2019) Critical success factors for programs in china: Construction companies' perspectives, *Journal of Management in Engineering*, 35(**1**).

Zhang, Q (1992) *Speech on the Opening Ceremony of the Research Committee of Project Way Construction Beijing (in Chinese)*. Available from http://www.cpmchina.com/Home [Accessed 24th April 2019].

Zhao, X Hwang, B-G and Low, S P (2013) Critical success factors for enterprise risk management in Chinese construction companies, *Construction Management and Economics*, 31(**12**), 1199-1214.

Zou, D and Zhang, X (1999) Investigation and analysis of 30 pilot state-owned enterprises for modern enterprise system, *Management World*, 1, 154-161 (in Chinese).

THE CONSTRUCTION INDUSTRY STAKEHOLDERS PRELIMINARY VIEWS ON THE PROPOSED SOUTH AFRICAN PROMPT PAYMENT AND STATUTORY ADJUDICATION REGULATIONS

Modupe Cecilia Mewomo[1]

Construction Management and Quantity Surveying, Durban University of Technology, Steve Biko Campus, Durban, 4001, South Africa

Payment default in form of delayed payment or non-payment is a key barrier to the survival of both contractors and sub-contractors in the construction industry. Delayed payments have not only negatively affected cash flow and progress of construction project but have, in some instances, resulted in protracted disputes thereby affecting the growth and performance of the construction industry. At present, payment default remains a chronic issue in the South African construction industry. This has become a source of concern to both the government and the construction industry. Following the successful adoption of the security of payment and statutory adjudication legislation in the United Kingdom (UK) and some other jurisdictions across the globe, the South African (SA) construction industry through the Construction Industry Development Board (CIDB) has prepared a prompt payment and statutory adjudication draft regulations. The regulation aims to address the peeved issues of late payment and provides a quick and cheaper means of resolving construction disputes through adjudication. At the moment, the draft regulation is awaiting approval. In anticipation of converting the draft regulations into law, this study investigates the industry stakeholders' first impressions of the proposed draft regulations, assesses their level of awareness and knowledge of the regulations and finally seeks their views on whether the regulations will be able to deliver its intended outcomes to secure timely payments in the industry. The study employs a quantitative research approach using a semi-structured questionnaire to gather information from various industry stakeholders within the KwaZulu-Natal Province of South Africa. The collected data was statistically analysed. The research revealed that the level of awareness is still very low. Moreover, opinion spilt as to the level of impressions that the respondents have regarding the regulations. Notwithstanding, majority of the respondents believed that the regulation should be able to deliver its intended outcome by providing remedy to the delayed payment problems in the industry.

Keywords: payment default, payment regulations, South Africa, statutory adjudication

INTRODUCTION

Late and disputed payment to contractors, sub-contractors or suppliers is an on-going problem in many construction industries across the globe (Nik Din and Ismail, 2014; Jin, Kumaraswamy and Gary, 2011). The South African construction industry is not spared in this unhealthy act (CIDB annual report, 2012; Maritz, 2014). In South

[1] modupemewomo@yahoo.com

Mewomo, M C (2019) The Construction Industry Stakeholders Preliminary Views on the Proposed South African Prompt Payment and Statutory Adjudication Regulations *In:* Gorse, C and Neilson, C J (Eds) *Proceedings of the 35th Annual ARCOM Conference,* 2-4 September 2019, Leeds, UK, Association of Researchers in Construction Management, 375-384.

Africa, delayed payments have traditionally been particularly common especially in public sector projects (Mewomo and Maritz, 2015; CIDB, 2015; Maritz and Mewomo, 2016). Often, the issue of delayed payments has not only resulted in protracted disputes and adversarial relationship between contracting parties but has significantly threatened the social and economic objectives of the country, thus affecting the national economic growth (CIDB, 2015; Rahman and Ye, 2010). Consequently, its disastrous effects have engendered serious concerns to both the government and various industry stakeholders as a good number of companies have been forced out of business due to late or non-payment. Small contractors and subcontractors' organisations are mostly affected as they require prompt payments for works executed in order to keep their businesses going. Unfortunately, these categories of organisations are faced with the dilemma of exercising their contractual and legal rights due to the cost and time involved as well as the fear of losing future job opportunities.

In the past, many regulative measures were introduced to address payment obligations, but most of them could not meet the demand of the industry. For instance, Act 1 of 1999, Section 38(1)(f) of the Public Finance Management Act (PFMA) requires accounting officers to settle all contractual obligations and pay all money owing, including intergovernmental claims, within the prescribed or agreed period. In addition, the National Treasury Regulation 8.23 states that: "Unless determined otherwise in a contract or other agreement, all payments due to creditors must be settled within 30 days from the receipt of invoice." Notwithstanding, despite the afore-mentioned regulations and many other similar ones, there has been a disappointing trend in the payment culture within the South African construction industry as timeous payment continues to deteriorate (CII, 2008, CIDB 2015). The CIDB Construction Indicators Report reveals the statistics of prevalent payment culture in the SA construction industry.

According to the 2014 edition, the report shows that a total of 58% of contractors suffered delayed payments. Fifty-three per cent of these contractors received payment for work done between 30-90 days, and 5% in 90 days or more (CIDB, 2014; CIDB, 2015). In 2015, 60% of payments to contractors were delayed for longer than 30 days after invoicing. This reflects a noticeable deterioration in prompt payment practices over the period 2012 to 2015. This practice is against the existing regulative measures and has put severe pressure on contractors and subcontractors, especially the emerging businesses who do not have sufficient capital (CIDB, 2015). Having realised the destructive effects of late payments on sustainability of entrepreneur and the survival of small and emerging contractors, both government and the industry have come to the realisation that delayed payment is a real threat, not only to small business, but to the very social and economic objectives of the country.

In line with this realisation, the CIDB believes that additional regulations and punitive measures are necessary to put an end to late payments (CIDB, 2015). This belief has propelled the CIDB to initiate the procedure stipulated in section 33 (Regulations) of the CIDB Act 38 of 2000 by drafting regulations in support of payment and adjudication practice in SA. The purpose of the regulation is to improve cash flow and provide quick access to justice through adjudication. Once enacted, the regulations are expected to ensure that there is actual cash flow in the construction industry (South African Construction News, 2015). According to Rabin and Schrag (1999), first impressions and initial responses of key stakeholders around new measures matter. Consequently, understanding stakeholders' views on new measures

may be one of the determinants of how effective the new regulation is likely to be and the level of benefits the industry can possibly derive from it. Thus, this study investigates the industry stakeholders' first impressions of the proposed draft regulations, assesses their level of awareness and knowledge of the regulations and finally seeks their views on whether the regulation is seen as a good move towards improving timely payment in the industry

LITERATURE REVIEW

The South African proposed prompt payment and adjudication regulations

In 2004, the CIDB introduced adjudication into construction contract in South Africa and advocated that: "adjudication should be applied to all categories of construction contracts, viz engineering and construction works, services and supplies, at both prime and sub-contractors' levels. Adjudication is meant to be a mandatory requirement for the settlement of disputes prior to the completion of contract" (CIDB, 2013). Through this initiation, construction adjudication found its way into two most famous locally developed construction agreement in South Africa; the General Conditions of Contract (GCC) 2004 and Joint Building Contracts Committee, JBCC 4th edition, consequently adjudication becomes a common place in South Africa. However, in contrast to the practice in other jurisdictions where adjudication is a creation of legislation, in South Africa adjudication can only be adopted by agreement between the contracting parties. As a result, the use of adjudication remains largely ineffective in the South African construction industry. Having realised the fact that the existing regulations may not be effective in the absence of statutory force, the CIDB in terms of the procedure stipulated in section 33 (Regulations) of the CIDB Act 38 of 2000 prepared a draft regulation in support of payment and adjudication practice in South Africa. The draft regulations were published for comments by the Minister of Public Works in Government Gazette 38822 of 29 May 2015.

The regulations were targeted at resolving cash flow issues by ensuring progressive payment to contractors/ subcontractors for work done. The proposed regulations governing payments and dispute management under construction contracts are expected to bring a great change into the way the South African construction industry operates. These regulations primarily address a crippling constraint to effective infrastructure development by introducing processes to ensure effective cash flow system in the industry. The draft regulations are in two parts. The first part, which is Part IV B tagged “Prompt payment”, provides a standard set of payment provisions which outlaw the practice of “pay when paid” or “pay if paid”; and support the entitlement to progress payment; date of liability for payment and provision of security and remedies for recovery of payment (CIDB, 2014). The second part, (Part IV C), introduces adjudication as a mandatory first step for resolution of disputes in both the public and private sectors. Several countries have already introduced Acts and Legislation to address payment default issues.

The scope of the Payment and Adjudication legislations in each jurisdiction (that has adopted it) is one of the main areas of divergence. While some jurisdictions include certain types of contracts in their Acts, some exclude them. Thus, the recognition of the types of contracts included in the Act to which the legislation refers is crucial in determining the beneficiaries that the legislation attempt to protect and thereby the legislation’s scope of application (Mewomo, 2016; Munaaim, 2012). Unlike other jurisdictions where the security for payment and adjudication were legislated in a new Act, the South African proposal for security of payment and adjudication legislation is

somewhat different and unique in that it is effectively subject to existing legislation and not to a separate new Act, as practiced in other jurisdictions. The CIDB Regulations published under GN 692 in GG 26427 of 9 June 2004 were amended by the insertion of part IV B and Part IV C. While the adjudication regulations provide the aggrieved parties with an effective means of redress against perceived wrongs, the payment regulations attempt to alleviate the problems of late payments which are so common within the construction industry. As such, the CIDB's prompt payment regulations in Part IV B is set to achieve the following objectives:

- statutorily prohibit "conditional payment' provisions e.g. 'pay-when-paid' clauses (Section 26B);
- improve payment process by insisting on regular payments within a defined time-frame - entitlement to progress payment (Section 26C);
- allow suspension of construction activities - right to suspend performance for non-payment (Section 26F);
- statutorily prohibit withholding of payment (Section 26E sub regulation 1, 6); and
- entitle a party to charge interest on late payments (Section 26D sub regulation 2);

In addition to the above-mentioned, the regulations provide for adequate mechanisms for determining the date of liability for payment under section 26D. The regulations require that every construction contract should provide a mechanism for determining when payment becomes due and payable under the contract. The date from which payment becomes due and payable is the date stipulated in the contract, provided that such date may not be more than 30 days after the date in which invoice was rendered (after which interest becomes payable). The purpose of the payment regulation is to address the payment issue which has been a serious problem within the industry. As such, the new proposed Payment and Adjudication regulations are expected to change the way the South African construction industry operates (South African Construction News, 2015). The introduction of the adjudication provisions in part IV C of the regulations would make it mandatory that construction contracts provide for the resolution of disputes by means of adjudication. In this way, each party to a construction contract would possess a statutory right to refer a dispute to an adjudicator, who would decide the dispute within twenty-eight calendar days. The adjudicator's decision will be binding on both parties until finally settled by arbitration, litigation or by agreement.

RESEARCH METHODOLOGY

This study adopted a quantitative research approach. However, in order to get more insight into the subject, the respondents were given opportunity to provide further information in form of comments. The quantitative research approach started with a review of relevant literature on security of payment, South African payment culture, the existing payment problems and the possible measures provided in the proposed regulations to combat the payment problems. This was followed by descriptive survey research. The survey research process involved the design and administration of a structured questionnaire. The designed questionnaires were sent to a total of 107 construction participants comprising contractors, sub-contractors, consultants in the KwaZulu-Natal (KZN) province of South Africa. About sixty-five per cent of the questionnaires were electronically mailed to industry stakeholders of which some are registered members of the Master Builder Association. Due to low response, some of

the questionnaires were distributed through face to face contact adopting convenience sampling. At the time of this preliminary survey, only 41 responses have been received on which this analysis is based. Therefore, the results are indicative of the condition in KZN and cannot be generalised to the rest of South Africa.

The questionnaire was sub-divided into three sections testing respondents' experience in payment default, the level of awareness and stakeholders' first impression of the proposed regulations, and general views on whether the proposed regulations will be able to deliver its intended outcomes to provide remedy to the delayed payment problems in the industry. A portion of the questionnaire provided an explanatory note to survey respondents. The explanatory note presented a brief summary of the provisions of the proposed regulations in order to enhance the respondents' knowledge on the intended purpose of the proposed regulations. In addition, efforts were made to further clarify issues regarding the regulations' provisions with those respondents that were met face to face. In order to determine the stakeholders' impressions on the proposed legislation, questions were asked as to the extent to which the respondents favour the provisions regarding regular payments within a defined time frame, provisions entitling a party to charge interest on late payments as well as banning of "pay if paid"; "pay when paid" provisions and mandatory statutory form of adjudication provisions in the proposed regulations.

The level of stakeholders' awareness and knowledge of the regulations could determine the rate of usage and adoption. Thus, a section of the questionnaire focused on determining the stakeholders' knowledge of the regulations and their level of awareness. The last section of the questionnaire was directed at examining the changes needed in the construction economics in order to support the effective implementation of the proposed prompt payment and adjudication regulations. The questionnaire used a five-point Likert type scale to measure a range of opinion from "very low" to "very high", "strongly disagree" to strongly agree' very uncommon to "very common", as the case may be. The respondents were requested to rate the level of their agreements on issues pertaining to the proposed draft regulations on the scale provided.

The analysis shows that respondents are involved at both private and public construction sectors of the industry. According to the statistics, 18 of the respondents operate in private sector, while 23 are involved in the public sector of the industry. Further, the analysis shows that 15 of the respondents were contractors, 19 were public clients while only 2 were sub-contractors. The years of experience of the participants vary, 27 had experience that ranges from 1-5 years, 10 had experience in the range of 6-10 years and 2 had experience that ranges between 11-15 years and 2 had more than 16years of experience in the construction industry. The analysis further reveals that 10 of the respondents' organisations had involved in 1-5 projects, 8 had worked in 6-15 projects, while the largest number of the respondents (22) had involved in more than 16 projects and are familiar with payment culture in the industry. This demographic information implies that the respondents have involved in a number of projects within the province and are suitable for this type of project which makes the data reliable. Moreover, considering the low responses from the survey research coupled with the facts that the study adopted convenience sampling approach, only the general views of the survey respondents were presented in this study. The differences in the views of different stakeholders were not considered in this study, as each strata /subgroup within the population were not equally represented.

Findings and Discussions

Trends Shown by the Data Collected

Stakeholders' experience in payment disputes

The first question under section 1 of the questionnaire was designed to gather information on the respondent's experience in payment default. The majority of the respondents (33) noted that their organisation had experienced delayed payments or non-payment in one or more of its projects. The minority of the respondents' (4) claimed that they had not experienced any delayed payments, while the remaining 4 of the respondents were neutral to the question. This result alludes to the fact that there exists a chronic problem of payment default in the South African construction industry (Maritz, 2007). A follow up question was asked to know the cases of disputes as well as types of disputes experienced by each of the respondents. Table 1 reveals that 29 of the respondents had experienced between 1 and 10 disputes over the period of 10 years, while only 3 had experienced more than 30 disputes in 10 years. The analysis further shows that the highest types of disputes experienced (43%) were caused by delayed payment by contractors to sub-contractors, followed by general payment/financial issues, and contractual claims which are 39% and 32%, respectively. Other types of disputes experienced include poor workmanship, delayed payment by client to contractors which are 29% and 10% respectively. It is not surprising that delayed payment by contractors is the most common type of disputes. This is in line with the report of CIDB which indicated that no less than 65% of subcontractors experienced delayed payment (CIDB, 2013). Most contractors delayed payments in order to increase their cash flow at the detriment of subcontractors (Lynch, 2011). Unfortunately, this unhealthy act continues to place small contractor in the construction industry at risk.

Table 1: Stakeholders experience in payment disputes

Cases of disputes	Frequency	Percentage (%)	Cumulative %
None	5	12	12
1-10	29	72	84
11-20	1	2	86
21-30	0	0	86
Above 30	3	7	97
Others	3	7	100

Table 2: Types of disputes experienced

Types of disputes	Frequency	Percentage (%)
Poor workmanship	12	29
Contractual claims	13	32
Breach of contract	4	10
Delayed payment by client	4	10
Delayed payment by contractors	18	43
General payment and financial issues	16	39
Consultants design deficiency	6	15

Stakeholders' responses on level of awareness, knowledge and impression on the proposed draft regulations

As noted earlier, the section 2 of the questionnaire focused on determining the level of awareness, knowledge and impression that the industry stakeholders have on the proposed regulations. Very few respondents' (only 3) rated their level of awareness of the proposed regulations as very high, 8 respondents noted that they have high level of awareness and 12 indicated they had average. The question regarding the level of knowledge of adjudication process and procedures indicates that only 1 respondent rated his level of knowledge and understanding as very high, 8 rated their level of knowledge high and the remaining 16 were neutral. The first impression on the regulations reveals that 3 of the respondents have very high impression, 13 respondents have high, while almost half of the respondents (20) rated their impression as average. It should be noted that as at the time of this survey, the regulations have not yet been implemented. However, the high number of respondents' who rated their impression from average to high and very high is a good indication that the industry stakeholders perceive the regulations provisions to be a positive and good move towards achieving improving cash flow in the industry.

Table 3: Summarised results on the level of awareness, knowledge and impression on the proposed regulations

Question	Low (No)	Very low (No)	Average (No)	High (No)	Very High (No)
Level of awareness	6	12	12	8	3
Level of knowledge	5	11	16	8	1
Impression on the payment regulations	1	4	20	13	3
Impression on the adjudication provision	2	3	15	19	2

The question on the impression on the proposed regulations was targeted at discovering how well the industry is ready and prepared to receive the regulations. Gary *et al.,* (2012) has noted the necessity of new legislation to be well received by the citizens, as it provides very good indication of its acceptability and future performance. The result from the survey data is a good indication that the industry is happy with the friendly provision of the proposed regulations. Nineteen (19) respondents rated their impression on the adjudication as high and, 2 very high while 15 rated their impression as average. Likewise, 13 respondents rated their impression as high for the proposed adjudication provision, 3 rated as very high and 20 rated it to be average. The fact that almost half of the respondents' rated their impression on payment provision as average shows that they are undecided, and their knowledge of its operation might have affected their decision. Notwithstanding, majority of the respondents opined that the regulations should be able to provide remedy to the delayed payment problems in the industry. More importantly, greater number of the respondents registered their agreement with the benefits that statutory adjudication under the proposed regulation has to offer (see Table 4)

Table 4: Summarised results on the benefits of adjudication as ADR

Question	Disagree (No)	Strongly disagree (No)	Neutral (No)	Agree (No)	Strongly agree (No)
Cost	1	5	11	17	7
Time	3	4	10	15	9
Privacy	-	6	12	17	6
Enforceability	3	4	11	21	1
Interim relieve	-	5	13	16	7
Fairness	-	5	8	19	9
Temporary binding decision	-	6	7	17	11

Stakeholders' responses on whether the regulations will be able to deliver its intended outcomes to secure timely payment and provide remedy to the delayed payment problems in the industry

Responses to the statement in section 3 of the questionnaire were intended to find out whether the respondents foresee any obstacles to the effective adoption of the proposed regulations and their suggestions on what possible means to avoid them. The first question under this category deals with the issue of business models that could impair the realisation of the intended outcomes of the proposed regulations. As earlier stated, this study did not consider the differences in the views of various industry stakeholders, notwithstanding, a cursory observation of the responses from sub-contractors group revealed that they supported the regulation provisions banning destructive payment terms. They however raised concerns on the issue of imbalance of power between main contractors and subcontractors. More concerns were raised on the possibility of main contractors using their superior power to hinder access to adjudication. Additional concerns were raised on the lack of knowledge of adjudication process and on whether the adjudication procedures will be simple or complex.

More apprehension was on whether an unpaid party can easily initiate the process irrespective of its status. Previously, within the industry, many subcontractors and small contractors had been confronted with the dilemma of exercising their legal and contractual rights and the fear of losing future job opportunities (CIDB, 2015), many of them chose to ignore their rights with the mind that 'Half bread is better than none' as they cannot afford protracted legal battles to force their clients/main contractors to pay. Presently, there is more concern that the big parties may utilise the skills of legal professionals such as claim consultants or lawyer and the small parties may thereby be at disadvantage if the procedure and process of adjudication is complex. The implication of these findings is that for the proposed regulations to be effective, the ease at which the smallest legally informed party can initiate the procedure should be put into consideration. Otherwise, some main contractors might possibly develop clever ways around legislation to delay payments. Issue regarding corruption and fear of losing opportunity to tender for future jobs were other major concerns raised by the contractor’s group. The contractor’s group suggested that for the proposed regulations to be effective, corruption must be preventable. Otherwise, there will be way around the "well-intended" provisions of the proposed regulations. The respondents finally believed that the regulations should be able to deliver its intended outcome by providing remedy to the delayed payment problems in the industry especially when there is improvement on construction economics within the industry.

CONCLUSIONS

This paper has presented the preliminary views of the industry stakeholders on the proposed draft regulations in the South African construction industry. Based on the survey feedback, the study provided confirmation that payment default remains a chronic problem affecting the delivery chain in the South African construction industry. As evident from the study, payment and financial issues are critical and have been found to be the root cause of disputes; most especially, delayed payment by main contractors/ clients. The proposed payment and adjudication regulation appear to be a very good and welcome idea by the industry. Notwithstanding, it appears that the payment provisions in the proposed regulations are of greater interest to the industry stakeholders as it received positive and high feedbacks.

Concerns were raised on some practices that can impair the effective adoption of the proposed regulations. These concerns ranged from lack of knowledge of adjudication process, the ease of access to adjudication, the complexity/simplicity of adjudication procedures, imbalance of power between contractors and subcontractors, the main contractors' business models / tactics through which contractors can develop clever ways around the regulations to delay payment, corruption and fear of losing future job opportunities. Certain suggestions were put forward if the purpose of the proposed regulations will be achieved. According to the sub-contractor's group, the ease at which the smallest legally informed party can initiate the adjudication procedure should be put into consideration. The contractors group suggested that for the proposed regulations to be effective, corruption must be prevented. More importantly, there is a suggestion that the current need of the industry is not only regulations, but the adoption of best practices, which will allow for a drastic change in the payment culture in such a way that the paymasters act justly, fairly and equitably by making the right payment due and in accordance with the applicable contractual obligations. These must be done within the confines of the universal notions of good conscience and justice.

This paper has been able to add to the existing body of knowledge by establishing that the proposed regulation is a good move towards promoting best practices between contracting parties, notwithstanding, corruption and other ill-practices must be prevented in order to realise the good and well-conceived provisions of the new regulations.

REFERENCES

CIDB (2003) *Procurement Practice Guide #C3 Adjudication*, The Construction Industry Development Board, Pretoria, South Africa.

CIDB (2012) *Annual Report of 2011/ 2012*, The Construction Industry Development Board, Pretoria, South Africa.

CIDB (2015) *Concrete, Issue 3, June 2015*, The Construction Industry Development Board, Pretoria, South Africa.

CIDB (2013) *Subcontracting in the South African Construction Industry, Opportunities for Development*, The Construction Industry Development Board, Pretoria, South Africa.

CII (2008) *The Construction Industry Indicators, Summary Results*, Pretoria, South Africa.

Gary, F S James, R M, David, G P and Collin, A B (2012) The new construction Act: Views and perceptions of construction industry stakeholders, *Structural Survey*, 30(**4**), 333-343.

Jin, W, Kumaraswamy M M and Gary S (2011) Regulative measures addressing payment problems in the construction industry: A calculative understanding of their potential outcomes based on gametric models, *Journal of Construction Engineering and Management*, 137, 566-573.

Lynch, P (2011) HGCRA: Re-addressing balance of power between main contractors and subcontractors? MSc, National Academy for Dispute Resolution, UK Available from http://www.nadr.co.uk/articles [Accessed: 8 October 2015].

Mewomo, M C and Maritz, M J (2015) An examination into the current status of adjudication practice on public sector construction contracts in South Africa, *Journal of Construction*, 8(**3**), 8-13.

Maritz, M J (2007) An investigation into the adjudication of disputes in the South African construction industry, In: *Proceedings of RICS COBRA Congress*, September, Atlanta USA, 419-426.

Maritz, M J (2014) Late payments continue to threaten the beleaguered construction industry, *Official Journal of South African Builder*, 10.

Maritz, M J and Mewomo, M C (2016) Towards effective implementation of adjudication as dispute resolution process on public sector projects in South Africa, Proceedings: The 40th Australasian Universities Building Education Association (AUBEA) 2016 Conference, 6 - 8 July 2016, Published by Central Queensland University, Bruce Highway, North Rockhampton QLD4702, Australia.

Mewomo, M C (2016) *Requirements for the Effective Statutory Adjudication Practice in the South African Construction Industry*. PhD Thesis, University of Pretoria, South Africa.

Munaaim, M E (2012) *Developing a Framework for the Effective Operation of Security of Payment Regime in Common Law Jurisdictions*. PhD Thesis, Kings College, London.

Nik DIN, N M D and Ismail, Z (2014) Construction Industry Payment and Adjudication Act (CIPAA) Remedying payment issues, *CIDB G7 Contractor's Perspective Journal of Technology Management and Business*, 1(**1**).

Rahman, H A and Ye, K M (2010) Risk of late payment in Malaysian construction industry, *International Journal of Mechanical and Industrial Engineering*, 4(**5**), 503-511.

South Africa Construction News (2015) *Regulation to Legislate Prompt Payments to Be a Game Changer for the Construction Industry.* Available from https://propertywheel.co.za/2015/06/regulations-to-legislate-prompt-payments-are-a-game-changer-for-the-construction-industry/ [Accessed: 21/07/2019].

DIGITAL CONSTRUCTION

DIGITALISATION AND INDUSTRIALISATION: EXPLORATION OF THE CURRENT AND FUTURE CHALLENGES IN THE SWEDISH BUILT ENVIRONMENT SECTOR

Annika Moscati[1] and Susanne Engström[2]

[1] *Construction Engineering and Lighting Science, Jönköping University, Gjuterigatan 5, Box 1026, 551 11 Jönköping, Sweden*

[2] *Department of Civil, Environmental and Natural Resources Engineering, Luleå University of Technology, 97187 Luleå, Sweden[2]*

Digitalization and industrialization are central topics in the Swedish government agenda and digitalization and industrialization of the built environment sector, as the largest single sector in Sweden, are with reason seen as crucial goals. In the Swedish strategic innovation programme Smart Built Environment (SBE), digitalization and industrialization are addressed and explored as a means to reduce environmental impact, planning and construction time, total construction costs, and to enable for new business logic in the built environment sector. One of the projects within SBE aims to measure effects and consequences of digitalization and industrialization to support the long-term assessment of the progress towards the programme goals. In this paper is presented the main findings from the first measurement, addressing a sample of SBE partners and their focus on digitalization and industrialization and what they perceive as the main challenges to reach the expected effects of changes and investments made in these areas during the period January 2016 - December 2017. Data presented in this paper was collected through dialogues, interviews and a questionnaire addressing SBE partners from companies, public organizations and agencies. Findings propose that much focus has been on digitalizing the information flow within and between organizations, yet many respondents state they now struggle with getting the organization and working methods "in place" to also benefit from the (mainly technical) investments made. Many respondents also express having implemented or at least initiated the implementation of applications in digitalization that are new to the Swedish built environment sector. Yet, there seem to be significant differences between what levels of digitalization different actors currently find themselves at, as well as what they are aiming for, which has implications for the efficiency of the information flow. Moreover, what is understood to contribute to further digitalization and a more unbroken information flow is described differently within as well as between organizations.

Keywords: digitalization, industrialization, information flow, BIM, change

INTRODUCTION

In Sweden as in many other countries, industrialization in construction has been proposed as means towards addressing perceived construction-industry problems such

[1] annika.moscati@ju.se

Moscati, A and Engström, S (2019) Digitalisation and Industrialisation: Exploration of the Current and Future Challenges in the Swedish Built Environment Sector *In:* Gorse, C and Neilson, C J (Eds) *Proceedings of the 35th Annual ARCOM Conference,* 2-4 September 2019, Leeds, UK, Association of Researchers in Construction Management, 386-395.

as high building costs, productivity falling behind other industries, and the overall environmental impacts of the building and construction sector (Goh and Loosemore 2017; Larsson *et al.,* 2014; Zhang *et al.,* 2016). Lately, digitalization has been added to, or even integrated with, industrialization and put forth as a key transformation route for prosperity, growth, and long-term sustainability (Isaksson *et al.,* 2018). However, it is unclear what digitalization means in terms of e.g. the effective actions building industries need to undertake.

The strategic innovation programme Smart Built Environment (SBE) is one of the larger current initiatives in Sweden focusing on industrialization, digitalization and how, in particular, the building and construction sector can contribute to the realization of new opportunities that digitalization brings. SBE is funded by government research councils (Formas, Vinnova, the Swedish Energy Agency) and has a broad foundation in the sector with partner organizations representing authorities, public and private building-process stakeholder organizations as well as digital developers. In SBE, industrialization and digitalization in construction is addressed and explored as the means to reduce environmental impact, planning and construction time, total construction costs, and to enable for new business logic in the built environment sector.

Started in January 2016, SBE is set to run for up to 12 years. To support the long-term assessment of the progress towards SBE goals a project has been assigned to measure effects and consequences of digitalization and industrialization during the length of the programme. The aim of this paper is to present some of the main findings from the first measurement, addressing a sample of programme partners and their focus on digitalization and industrialization during the period January 2016 - December 2017. More specifically, in this paper is addressed the expected effects of changes and investments made in these areas and what the addressed programme partners perceive as the main challenges to reach these effects. From findings, the authors will argue that: despite most of the previous conducted researches focus on technical tools current challenges to develop digitalization may rather be found in accomplishing concrete changes in organizations, and; a reason for such a slow digitalization process in the building sector might be found in different views of digitalization held by interacting organizations.

Expected effects and challenges highlighted in literature

The promising effects of digitalization has frequently been promoted by consultancy firms, for example McGrawhill Construction (Smart Market Reports, 2010, 2012, 2014) and by researchers, sometimes a bit uncritically (Dainty *et al.,* 2017), claiming that the introduction of digital technology or tools in the construction sector will help increasing efficiency, productivity and performance. In particular, digitalization of standardized information flows is proposed as means to provide new methods for information exchange and coordination between all actors in the building process (see Andersson and Lessing, 2017). However, the introduction and implementation of industrialization and digitalization in construction has till now been far from straight forward. Researchers have proposed and reported on challenges and problems needed to be overcome in order for sector transformation to progress, and for organizations in the sector to benefit from any transformation taking place.

Research has frequently addressed the potential of technical solutions of different kinds and thus, technical matters regarding software/hardware compatibility have typically been in focus. Researchers have also suggested that whereas organizations

recognize the capital investment needed in information technology (typically in software and hardware), the return of such investments are considered to be unclear as well as uncertain (Liu *et al.,* 2017). Besides investments in information technology competencies also need to be developed (ibid.) in order for the investments to be implemented and put into proper use. Redwood *et al.,* (2017), Ghaarianhoseini *et al.,* (2017) and Eadie *et al.,* (2013) argue for example that organizations reject investments in digital technology due to not only perceived cost of technology investments but also due to such things as a lack of skills and experience in using the new technology or software, and thus not being confident about their organizational ability to attain expected gains in efficiency.

BIM (building information models/modelling/management) as well as lean construction has during recent years been closely related to industrialization and digitalization in construction. Saieg *et al.,* (2018) argue that with BIM we can affect quality, productivity, efficiency and gain sustainable benefits. Yet they state BIM technology and lean management in organizations are in the beginning of the learning phase (ibid.). BIM based lean tools also need more experienced, trained and active stakeholders to realize its potential. Moreover, technical matters in need for better attention according to Saieg *et al.,* (2018) include integrated and interoperable information systems, and investments in equipment, technologies and user-friendly interfaces are called for. When it comes to building the model, Pinheiro *et al.,* (2018) found that when there is a collaborative environment where all project stakeholders are involved and included at the early stage of the project an effective exchange of information between the disciplines is facilitated and, thus, the necessary information can be included in the model. Eadie *et al.,* (2013), in their study in UK focusing on measuring the impacts of BIM use throughout the project lifecycle, also infer that BIM is primarily used at the early stage of the project for designing, visualization, procurement and for construction, manufacturing and coordination; whereas it is less used at the later stages of the project for commissioning as well as for facility management, retrofit and demolition stages.

According to Liu *et al.,* (2017), BIM is more of a process than a software. Still, Merschbrock and Munkvold (2015) showed in their study addressing BIM deployment in a major hospital construction project in Norway that most of the companies thought that BIM is for creating 3D models and visualization only. Very few companies, the researchers conclude, did consider it for creating semantic rich BIM models or used it for creating multidisciplinary models (ibid.). Researchers such as Arayici *et al.,* (2018) also infer that sustainable projects call for multi-disciplinary involvement and collaboration, but BIM-use from this view is not common practice. Acknowledging BIM as a common reference and example of digitalization, frequently related also to industrialization in construction, research seems to indicate that the understanding as well as the realization of potential is limited and potentially differing between different stakeholders (ibid.).

Diaz *et al.,* (2017) stated that the main barrier is changing the working method from 3D method to programming. Other researchers have proposed that people and organizations being used to their traditional working process may simply not be ready to change so that the digital transformation can take place, and that lack of knowledge together with lack of motivation among construction organization members regarding the use of new digital technology in the project is a major problem for progressing digitalization in construction (see e.g. Pauwels *et al.,* 2017; Corry *et al.,* 2014).

METHODOLOGY

The methodological approach selected for this study was designed to measure the Swedish building sector's level of digitalization and industrialization and to detect any hinder to pursue the scope of the programme. The research includes the collection of qualitative and quantitative data that are analysed through a theoretical framework based on scientific references selected from an international scenario. The theoretical frame of reference has been structure to investigate the following main topics: digitalization, industrialization, technical or organizational issues among the building sector. In order to trace the achievement of the SBE programme's goals, measurements with relevant partners are planned to be conducted every other year. In this paper the authors present findings of a first measurement conducted through twelve in-depth interviews and a questionnaire addressing a sample of partners (response rate 17/25) in the Smart Built Environment programme including: materials and components suppliers, consultants, architects and engineering companies, contractors, client, facility managers, property owners and public authorities. The questionnaire was developed through dialogues with a reference group of construction management researchers and with representatives from the sector. It included 66 questions structured in the following thematic areas:

- Digitalization and Industrialization
- Development and change work practice during the period 2016-2017
- Information Flow, including:
  i) BIM and GIS integration
  ii) Open data
  iii) Object-based information
  iv) Digitalization and data sharing
- Environmental and energy declarations

Dialogues to develop the questionnaires, in-depth interviews addressing expectations, current developments and understandings among SBE partners regarding digitalization, industrialization and SBE effects and goals, the questionnaire part of the measurement, and follow-up dialogues with responding organizations were conducted in several rounds from February 2017 to August 2018.

FINDINGS

Findings show that much focus among addressed organizations has been on digitalizing the information flow within and between organizations by introducing different technical tools and solutions. Most parties talk about digitalization in terms of information modelling and information management. However, the typical answer concerns the creation of digital data, information models and object-based information, mainly 3D objects and/or BIM.

> [Current use of digitalization includes] 3D models with information, digital drawings. (Contractor)

> We demand for 3D object and model-based design. (Property owner)

Despite that, some organizations have limited perceptions of or make limited use of BIM opportunities, mainly because their clients are not willing to pay for something, they do not have any use of.

The digital transformation, as described by those who participated in the survey, primarily involves a transition from paper-based documentation and distribution to digital documents, but also from digital documents to digital data.

> [...] we have reduced our handling and distribution of paper documents during the planning process, referring to a greater extent to our webpage and screens at the municipality service centre. (Local planning authority)

> We convert conventional drawing material into BIM models, filling them with property-related data and present the results in our web archive for property management. [The focus of development efforts during the past two years include] accessing and providing environmental data which can better enable for LCA and LCC estimations. (Consultancy agency)

Some parties, mainly consultants, describe the use of digital data for different analyses in different systems aiming to a digitalized/automated information retrieval. Concerning industrialization, the respondents' most common descriptions refer to standardization and prefabricated artefacts. They emphasize the lack of standardization (linked to methods, routines and working methods) as the cause or explanation for the reliability issues regarding digital data, and as an obstacle to/enabler for the digital information flow. Typical answers for application of industrialization relate to prefabrication and pre-planning. In some cases, the application is found within the organization or the business operations. In other cases, the application is mainly associated with construction production conducted by other actors (applies mainly to clients and authority side).

> I connect our application of industrialization in construction with our use of prefabricated products and so-called type houses. (Property owner)

Different understandings of digitalization

An important prerequisite for being able to share data digitally between different actors is that data to be shared is in digitalized form. Most of the parties who answered the questionnaire state that they have allocated resources to digitize internal analogue data and/or that they have taken measures such as require the delivery of digital data from the partner companies. What the parties in the survey seem to have been digitizing to a large extent are errands, delivery descriptions, drawings and related documents. However, despite that all the organizations involved in the study claimed to have invested capital and time toward a more digitalized process and an improved digital information flow, their efforts pointed to different directions. Some organizations, mainly public authorities, seem to have invested significant resources on digitizing analogue documents by scanning and storing them as, for instance, PDF-files.

> […] for example, on the building permit department, we have digitized one archive. Two people were employed full time for about six months in order to scan (analogue) drawings and documents. (Local public authority)

At the same time and suggesting a different view of digital information and digitalization, other organizations claimed problematic the definition of "PDF-files as digital information" since data cannot be directly extracted and processed. One organization even claimed that pdf documents are not to be understood as digital information or data.

> Digitalization is far from fully developed. […] We receive instead fully non-digital documents such as […] pdf documents without any data that can be transferred digitally and in a standardized manner to for example calculation models. (Component supplier)

Some of the consultants' state that working with digital data enables an improved information flow, better coordination of information and the performing of analyses and calculations. From their perspective scanned documents and practices similar to what is described in the quote above do not further digitalization.

(Digital) Information flow

As already indicated above, the respondents' answers to questions about what primarily contributes to a more unbroken (digital) information flow show a variety of views and different focus. Recurring, however, is the development and increased use of "models" (digital, 3D/BIM, object-based information solutions) described as important contributors in this development.

> We have digital case management with standard workflows; [we] work with standard layouts in projects including LOD (Level of Development). (Consultancy agency)

Testing in ongoing construction projects appears to affect various aspects of the information flow among the parties. However, from the questionnaire and interview responses, public authorities do not appear to be involved to any great extent in tests on ongoing construction projects, or the involvement of authorities is not well communicated or known. At an overall level, tests in ongoing construction projects in several cases deal with trying something perceived "as new" e.g. moving from (paper) drawing usage to, instead, using digital information models (only).

Answers in the questionnaire indicate that most parties believe to have approached a more unbroken digital information flow during the period January 2016 - December 2017, which was also confirmed during dialogues and interviews. Two of the organizations addressed in the study did not believe their organization approached a more unbroken (digital) information flow, stating that the introduced digital applications have contributed to an increased (technical) ability to exchange information with external parties, but that the information flow thus cannot be considered "more unbroken" as, for example, routines and working methods are not yet fully developed.

Need for focus change: from technology to organization

Organizational changes are described as prerequisites for being able to benefit from investments made in the field of digitalization. So far, according to the questionnaire respondents, such changes have mainly concerned changed working methods, structures and roles. Respondents from different branches of the civil engineering sector also express a continuous need to get the organization and working method "in place" to achieve the expected and measurable effects of digitalization. Challenges related to managing the transition as identified by respondents include creating the incentives for behavioural changes and coming to a common understanding of how to do things in a new yet coordinated way within as well as between organizations.

> Changing working methods rises uncertainties about [employees] behaviour. It does not have to do with the lack of [technical] competences, but rather with the lack of incentives that stimulate the changes for the individuals. (Client/Facility manager)

> For some reasons, everyone always wants to invent their own instructions, own copies of data, etc. This is very much based on the lack of competence and insight I believe. (Consultant)

> I find that in many cases we work with quite sophisticated tools, but that we hardly know where the steering wheel is. It is for example still a challenge to get designers delivering an IFC with the correct classification. [...] Not more than 50-70% of the files

> follow the instructions. If we do not deal with these basic conditions, it is difficult to integrate and automate. (Consultancy agency)

Findings from one of the addressed organizations also indicate that the opportunity of introducing solutions to support the flow of information may call for mapping and assessing how information currently flows in the organization. From this organization it is further highlighted that organizations need to understand what the new organization and working methods should be to enable for a more digital flow of information, as well as that there is the potential need to develop an organization (in this case a team organization was created) to plan and prepare for the transition itself:

> 'Digitization and teamwork' has been a topic for the urban planning office in recent years, especially from 2016 […]. The building permits department has worked extensively to establish a changed working method and to move towards a completely digital building permit process and working in teams. […] During the second half of 2017, we have also increased focus on the digitization of the planning process and worked with reduced paper-based mailings during consultation and review. Great focus [has been put] on teams with effective flows between departmental boundaries (Public organization).

DISCUSSION

Findings propose that much focus among addressed organizations has been on digitalizing the information flow within and between organizations by introducing different technical tools and solutions. Thus, the focus of organizations seems to reflect well the focus of research on digitalization in construction which to a great extent has focused on technical tools, technical systems and technical structures, including the development of features and possibilities as well as addressing technical problems hampering a more widespread adoption and use (Andersson and Lessing, 2017; Liu *et al.,* 2017).

Though compatibility still is a concern to some of the addressed organizations, many seem to be at a point where their primary struggle is not with hardware and software but rather with getting the organization and working methods “in place” (Redwood *et al.,* 2017; Ghaarianhoseini *et al.,* 2017; and Eadie *et al.,* 2013). To some extent the latter refers to what can be understood as a generic competence-related need i.e. being able to use the technical tools in day-to-day work. But as highlighted by some respondents getting the organization and methods "in place" has also to do with gaining leverage from the technical competences and digital capabilities the organization has already invested in, acknowledging for example the need for common understandings and agreements on how to do things in a new way as well as presenting proper incentives for humans to change.

Hence, moving from the technical to the organizational seems to involve doing things differently rather than simply using available tools in response to direct/explicit demands from clients and other stakeholders. To benefit from the (mainly technical) investments made such transformation seems to be on top of the digital challenge among several of the addressed organizations, where the challenge is generally described in terms of being greater or more problematic to address and solve than are those challenges which concern technical matters, or could be solved by further investments by the organization in technical tools and technical infrastructure.

Moreover, organizations seem to agree that in order to progress towards a more unbroken digital flow of information the actions of many stakeholders are of importance. Yet, how digitalization is actively progressed as well as what is

understood to contribute to further digitalization and a more unbroken information flow seems to be described differently within as well as between organizations. First, besides the differences between what levels of digitalization different actors currently find themselves at there seem to be differences regarding what they are aiming for; i.e. whereas some of the organizations intend to move towards digitalizing data others are currently focussing significant resources on digitizing analogue documents by scanning and storing them as e.g. PDF-files. The potential implications for the efficiency of the information flow include methods for information exchange and coordination between all actors in the building process (see Andersson and Lessing, 2017). Second, the most common description of digitalization in terms of current practice in the addressed organizations relates to 3D-models and BIM. The use of BIM and the development and use of object-based models is referred in the Smart Built Environment programme, as well as by respondents, as one important progression towards better managing building information using digital opportunities. However, similar to Gemalto (2018) findings suggest that some organizations have limited perceptions of or make limited use of BIM opportunities. When these organizations are found on the demand side of construction the potential of BIM use for maintenance and lifecycle use is not realized at the beginning of the project, since clients are not willing to pay for value they do not foresee or expect, and thus, the limited perception and use becomes a self-fulfilling prophecy.

The findings from the first measurement seem to indicate different views on further developments of digitalization and digital flow of information. There is the difference between finding ways of digitalizing the current flow of information and to make use of digitalization to rethink and improve the flow. On the other hand, there is the difference between understanding the flow of information as a necessity to realize and maintain the physical (constructed or built) asset or envisioning the information as an asset itself.

CONCLUSIONS

Based on the findings and as argued in the preceding discussion, the authors propose that though much research have focus on technical tools to develop digitalization, organizations currently seem to struggle more with organizational and human matters. The authors also propose that a significant reason for such a slow digitalization process in the building sector might potentially be found in different views of digitalization held by different interdependent organizations, as demonstrated by the partners participating in this research.

The organizations' perceived main challenges to reach the expected effects of changes and investments made toward a digitalized building process seem to include such matters as:

- the development of working methods and organizational structures to benefit from previous, ongoing and planned investments in technical solutions
- the management of change, including the development of technical know-how capabilities as well as that of human mind-sets and behaviours
- the views of information as value and asset
-

These challenges do seem to indicate a shift from technical concerns to social and economic which, in turn, might be understood as a challenge not only for the organizations in this study but as the collective challenge for the research community.

This latter is called to further investigate organizational and social matters toward a digitalized building process, taking into account all the interested parties.

ACKNOWLEDGEMENTS

We gratefully acknowledge the engagement of organizations participating in the first measurement as well as the strategic innovation programme Smart Built Environment for the financial support.

REFERENCES

Andersson, N and Lessing, J (2017) The Interface between industrialized and project-based construction, *Procedia Engineering*, 196, 220-227.

Arayici, Y, Fernando, T, Munoz, V and Bassanino, M (2018) Interoperability specification development for integrated BIM use in performance based design, *Automation in Construction*, 85,167-181.

Cao, D, Wang, G, Li, H, Skitmore, M, Huang, T and Zhang, W (2015) Practices and effectiveness of building information modelling in construction projects in China, *Automation in Construction*, 49, 113-122.

Corry, E, O'Donnell, J, Curry, E, Coakley, D, Pauwels, P and Keane, M (2014) Using semantic web technologies to access soft AEC data, *Advanced Engineering Informatics*, 28(**4**) 370-380.

Dainty, A, Leiringer, R, Fernie, S and Harty, C (2017) BIM and the small construction firm: a critical perspective, *Building Research and Information*, 45, 696-709.

Diaz, H, Alarcón, L F, Mourgues, C and García, S (2017) Multidisciplinary Design Optimization through process integration in the AEC industry: Strategies and Challenges*, Automation in Construction*, 73, 102-119.

Eadie, R, Browne, M, Odeyinka, H, McKeown, C and McNiff, S (2013) BIM implementation throughout the UK construction project lifecycle: An analysis, *Automation in Construction*, 36, 145-151.

Ghaarianhoseini, A, Tookey, J, Ghaffarianhoseini, A, Naismith, N, Azhar, S, Efimova, O and Raahemifar, K (2017) Building Information Modelling (BIM) uptake: Clear benefits, understanding its implementation, risks and challenges, *Renewable and Sustainable Energy Reviews*, 75, 1046-1053.

Goh, E and Loosemore, M (2017) The impacts of industrialization on construction subcontractors: A resource-based view, *Construction Management and Economics*, 35(**5**), 288-304.

Hosseini, M R, Banihashemi, S, Rameezdeen, R, Golizadeh, G, Arashpour, M and Ma, L (2017) Sustainability by information and communication technology: A paradigm shift for construction projects in Iran, *Journal of Cleaner Production*, 168, 1-13.

Isaksson, O, Hallstedt, S I and Rönnbäck, A Ö (2018) Digitalisation, sustainability and servitisation: Consequences on product development capabilities in manufacturing firms, *In*: *Proceedings of Norddesign: Design in the Era of Digitalization*, 14-17 August, Linkoping, Sweden.

Larsson, J, Eriksson, P E, Olofsson, T and Simonsson, P (2014) Industrialized construction in the Swedish infrastructure sector: Core elements and barriers, *Construction Management and Economics*, 32(**1-2**), 83-96.

Leviäkangas, P, Paik, S M and Moon, S (2017) Keeping up with the pace of digitization: The case of the Australian construction industry, *Technology in Society*, 50, 33-43.

Liu, Y, Van Nederveen, S and Hertogh, M (2017) Understanding effects of BIM on collaborative design and construction: An empirical study in China, *International Journal of Project Management*, 35(**4**), 686-698.

Merschbrock, C and Munkvold, B E (2015) Effective digital collaboration in the construction industry-A case study of BIM deployment in a hospital construction project, *Computers in Industry*, 73, 1-7.

Pauwels, P, Zhang, S and Lee, Y C (2017) Semantic web technologies in AEC industry: A literature overview, *Automation in Construction*, 73, 145-165.

Pinheiro, S, Wimmerb, R, O'Donnell, J, Muhic, S, Bazjanac, V, Maile, T, Frisch, J, and Treeck, C (2018) MVD based information exchange between BIM and building energy performance simulation, *Automation in Construction*, 90, 91-103.

Redwood, J, Thelning, S, Elmualim, A and Pullen, S (2017) The proliferation of ICT and digital technology systems and their influence on the dynamic capabilities of construction firms, *Procedia Engineering*, 180, 804-811.

Saieg, P, Sotelino, E D, Nascimento, D and Caiado, R G G (2018) Interactions of building information modelling, lean and sustainability on the architectural, engineering and construction industry: A systematic review, *Journal of Cleaner Production*, 174, 788-806.

Santos, R, Costa, A A and Grilo, A (2017) Bibliometric analysis and review of Building Information Modelling literature published between 2005 and 2015, *Automation in Construction*, 80, 118-136.

Smart Market Report (2010) *The Business Value of BIM in Europe Mcgraw-Hill Construction - Getting Building Information Modelling to the Bottom Line in the United Kingdom, France and Germany*. Bedford, MA: McGrawhill Construction.

Smart Market Report (2012) *The Business Value of BIM in North America - Multy-Year Trend Analysis and User Rating (2007-2012)*. Bedford, MA: McGrawhill Construction.

Smart Market Report (2014) *The Business Value of BIM in Australia and New Zealand: How Building Information Modelling is Transforming the Design and Construction Industry*. Bedford, MA: McGrawhill Construction.

Takim, R, Harris, M and Nawawi, A H (2013) Building Information Modeling (BIM) A new paradigm for quality of life within Architectural, Engineering and Construction (AEC) industry, *Procedia-Social and Behavioural Sciences*, 101, 23-32.

Volk, R, Stengel, J and Schultmann, F (2014) Building Information Modeling (BIM) for existing buildings - Literature review and future needs, *Automation in Construction*, 38, 109-127.

Zhang, J, Long, Y L S and Xiang, Y (2016) BIM-enabled Modular and Industrialized Construction in China, *Procedia Engineering* 145, 1456 - 1461.

.

APPLICATIONS OF VISUALISATION TECHNOLOGY IN CONSTRUCTION SAFETY TRAINING: A PRELIMINARY REVIEW

Rita Peihua Zhang[1], Clara Man Cheung[2] and Hou Lei[3]

[1] *School of Property, Construction and Project Management, RMIT University, GPO Box 2476, Melbourne, Victoria, 3001, Australia*

[2] *School of Mechanical, Aerospace and Civil Engineering, The University of Manchester, Oxford Road, Manchester, M13 9PL, UK*

[3] *School of Engineering, RMIT University, GPO Box 2476, Melbourne, Victoria, 3001, Australia*

The construction industry is a hazardous industry and characterised by high number of workplace injuries and fatalities. Research evidence indicates that risk factors such as a lack of trade knowledge and skills, inadequate understanding of risk controls, and low level of safety awareness can contribute to workplace accidents. This highlights the importance of training in assuring that workers competently perform work tasks by adhering to health and safety requirements. The conventional way of developing safety knowledge and compliant skills is to attend classroom-based training on safety procedures and related codes of practice. However, such a training approach has long been questioned about its effectiveness due to low level of engagement and lack of opportunities to practice in a real site scenario. Emerging visualisation technologies such as virtual reality (VR), augmented reality (AR) and gaming environments seem promising to overcome the limitations of traditional training approach. Researchers have attempted to develop various visualisation technology-enabled training systems or approaches to enhance training effectiveness. However, a systematic understanding of what and how visualisation technologies have been used to support safety training is missing. A study is being initiated to systematically review literature to examine the status of visualisation technology-enabled training approaches in construction. This paper reports the preliminary results from a pilot study. The results indicate that the application of visualisation technologies in safety training is still in the early stage. Existing applications primarily have focused on hazard identification and specific work tasks, but haven't considered broader contextual factors (e.g. construction types, training needs in project lifecycle), pedagogy (e.g. learning methods), learners' characteristics (e.g. experience, skills), etc. A four-dimensional framework is suggested in this study to provide directions for future research in applications of visualisation technologies in safety training.

Keywords: safety, training, visualisation technology, worker skills, review

INTRODUCTION

The construction industry has long been considered as a hazardous industry with alarming statistics of construction workplace injuries and fatalities recorded. For

[1] rita.zhang@rmit.edu.au

Zhang, R P, Cheung, C M and Lei, H (2019) Applications of Visualisation Technology in Construction Safety Training: A Preliminary Review *In:* Gorse, C and Neilson, C J (Eds) *Proceedings of the 35th Annual ARCOM Conference,* 2-4 September 2019, Leeds, UK, Association of Researchers in Construction Management, 396-405.

example, in Australia, the construction industry accounted for 9% of the Australian workforce but 10% of workers' compensation claims for injuries and diseases involving one or more weeks off work during 2012-2013 (Safe Work Australia, 2015). In addition, 153 worker fatalities were recorded in the Australian construction industry during 2013-2017, which accounted for 16% of total worker fatalities (Safe Work Australia, 2017). The construction industry has been identified as a priority industry by the Australian Work Health and Safety Strategy 2012-2022 for developing prevention strategies to reduce injury and fatality rates (Safe Work Australia, 2012).

Haslam *et al.,* (2005) analysed 100 construction accidents, and reported that the factor of worker capabilities (including knowledge/skills) was involved in 42% of the accidents. They further pointed out that underlying this analysis result is workers' inadequate safety knowledge as well as deficiencies with safety training. The development of effective training approaches to increase workers safety competence has been highlighted as an important strategy to prevent injuries and fatalities (Wilkins, 2011). The Australian Work Health and Safety Strategy has defined one of the national Action Areas as "Health and Safety Capabilities" and specified that work health and safety skills development should be integrated effectively into relevant education and training programs (Safe Work Australia, 2012).

Safety training has been conventionally provided in a classroom setting facilitated by a trainer with text-based or imaged-aided instructions. The classroom-based training is normally conducted in the form of lectures with the main purpose of disseminating safety-related information, e.g. safety policies, procedures, rules and code of practices. This conventional training approach has received many critiques regarding its' effectiveness. For example, Burke *et al.,* (2006) described the lecture form of training as passive and "least engaging" methods of safety training. There is little opportunity for workers to interact with practices and gain hands-on experience. Wilkins (2011) examined workers' perceptions of a classroom-based OSHA 10-Hour Construction Safety Training Course, and reported that many workers were dissatisfied about the course due to various reasons, including the difficulty in understanding training material, the irrelevance of training content to their work practices, and the incompetency of trainers who largely failed to address adult learning characteristics.

Emerging visualisation technologies, such as virtual reality (VR), augmented reality (AR), mixed reality (MR) and gaming environments, are gaining increasing attention from researchers regarding their potential to overcome the limitations associated with traditional training approach. Training approaches enabled by those visualisation technologies are highly engaging in nature, and emphasize behavioural modelling, e.g. observing a role model, modelling or practice, and assessment or feedback designed to modify behaviour (Burke *et al.,* 2006). These approaches also often involve hands-on demonstrations associated with behavioural simulations, which provides a highly participatory experience for trainees (Burke *et al.,* 2006). The practice-based learning potentially improves knowledge acquisition, retention, and training transfer.

Despite the existing efforts in designing technology facilitated training systems or approaches, so far there hasn't been a systematic understanding of what and how different visualisation technologies have been used in safety training, and what aspects can be further improved to achieve more effective training outcomes. A study is being initiated to systematically review literature to explore answers to those questions. This paper only reports preliminary results from a pilot study.

LITERATURE REVIEW

Visualisation technologies have gained applications in complex machinery operation training and complex procedural skills development. For instance, the risk of being crushed against overhead structures is ever present and therefore should never be overlooked. Several situations can lead to crushing, but operators have reported the lack of operational proficiency, i.e. dealing with complex panel functions and varied control suites, is a major problem (Hou *et al.,* 2017). This has aggravated the sophisticated nature of operating auxiliary equipment in line with the demands of large-scale complex asset maintenance projects such as mining equipment, liquefied natural gas facilities and power plants (Krasnyanskiy *et al.,* 2014). The substance of prior-task preparation and planning is placed on the integration of complex procedural training and human factors as they relate to improvement of cognitive skills as well as the deployment of advanced visualisation technologies to achieve better outcomes in, for example, the machine operation case. Training for the operation of increasingly complex machinery and complex procedural tasks using such machinery benefits from visualisation technologies and will expand into complex procedural support.

VR, AR and MR technologies have also been widely developed to generate interactive training settings and proved to be conducive to high-risk and inaccessible work environments (Ioannidis *et al.,* 2014). The shift from current in-class and equipment-based training to portable visualisation technologies is an innovation that allows training delivery onsite for workers and operators. The portability benefits afforded by visualisation paradigms integrated into training curriculums will assist asset companies with workers and operators located on widely dispersed sites to benefit from productivity gains. The significant benefits from moving away from complete immersion administered via costly, centralised high-fidelity interfaces has been acknowledged as beneficial in other sectors as well.

In addition, it is preferred that whatever actions that will be taken can be fully rehearsed in advance and/or well instructed during the task. Things such as task duration, workplace access and safety, ergonomic factors, if can be made known to the crew upfront, will be able to improve the crew's awareness to the task context. Site access and personnel evacuation problems have recently attracted significant research attention, resulting in diverse applications and optimisation solutions (Tsai *et al.,* 2012). The awareness of workspace contexts and uncertainties, if gained by human operators, would greatly reduce the probability of accidents while the task is in progress. AR and MR technologies that enable a visual and perceptive connection between a physical workspace and a virtual counterpart, can be leveraged to facilitate such awareness and fulfil safety considerations (Irizarry *et al.,* 2013).

Construction tasks normally involve multiple collaborative entities such as workforce, physical presence, schedule, information, materials, tools, equipment and assets. These tasks require high level manipulation skills, problem-solving strategies, hazard awareness and decision-making based on knowledge of occupational health and safety requirements. Studies prove that 35-45% of working time of taskforce is spent in looking for the right information, provided the common approach of information retrieval being paper-based drawings (Ruwanpura *et al.,* 2012). However, traditional presentations of work plans or drawings could be misinterpreted, imprecise or outdated. The digital visualisation of information contained within BIM can provide those on-site personnel with an improved understanding of task sequencing, which will reduce the incidence of quality and accuracy failures. Holding a tool or a work

piece while looking for information could easily distract a technician from the work task he is undertaking, whereas AR and MR concepts can be leveraged to make information readily available and expedite asset tasks with efficiency and effectiveness guaranteed (Hou and Wang 2013). For example, information (retrieval and display) would be integrated with views of the work piece if the technician wears a head-mounted display (HMD).

AR technologies show the potential to support maintenance decision making and improve the human performance for technical maintenance tasks (Palmarini *et al.,* 2018). To increase the efficiency, operating savings and reliability of railway assets, Hall *et al.,* (2015) developed a tablet-based asset management platform which can overlay AR clues onto a view of the railways. The haptic features incorporated in this system involved AR graphics, VR video, as well as sensor-gathered sound and location data. When integrated with BIM technologies, tablet-based AR has the potential of providing asset managers with mobile access to their required asset information. On the other hand, a finer asset practice would need the practitioners to shed light on not only better AR/BIM interfaces, but also more streamlined asset management processes that support digital work manners (Gheisari and Irizarry 2016).

The various applications of visualisation technologies presented in the literature review provide implications for using those technologies in the construction industry. However, the utilisation of visualization technologies in construction skills training and particularly in safety training is not much prevailing comparing with that in other industries (Park and Kim, 2013). There is a need to examine the status and potential of visualisation technologies in supporting safety related training in construction.

RESEARCH METHOD

This pilot study was conducted with a small-scale literature review. The database of ScienceDirect was used to search a list of studies in relation to the application of visualisation technologies in safety related training in construction for the pilot study. This database was chosen because it contains many scientific and engineering journals that are relevant to the construction safety area. The predefined key words of ("virtual reality" OR "augmented reality" OR "mixed reality" OR "immersive environment") AND training AND construction AND safety were used to search relevant literature within the range of years 2000-2019. The searching results were restricted to those publications that have the predefined keywords appear in publication title, abstract or author-specified keywords. A total of 13 publications were sourced through the searching process. A screening process indicated that two publications were literature review papers, one publication discussed how to use VR to capture building users' performance, while another publication discussed how to use tracking system and VR to analyse workers' postures while working and categorised work tasks into ergonomic or non-ergonomic categories. These four papers were excluded from further review and analysis. Table 1 lists the summary information of these papers.

Table 1: Summary of the publications sourced for analysis

Authors (Year)	Journal title	Country of study
Azhar (2017)	Procedia Engineering	USA
Cheng and Teizer (2013)	Automation in Construction	USA
Goulding *et al.*, (2012)	Advanced Engineering Informatics	UK
Hou *et al.*, (2017)	Automation in Construction	Australia
Kim *et al.*, (2017)	Automation in Construction	Korea
Li *et al.*, (2012)	Automation in Construction	Hong Kong
Park and Kim (2013)	Automation in Construction	Korea
Perlman *et al.*, (2014)	Safety Science	Israel
Teizer *et al.*, (2013)	Automation in Construction	USA

The remaining nine publications were subject to a critical review and theme coding by researchers. The main purpose of the literature analysis was to explore: 1) what and how visualisation technologies have been applied in safety-related training in the construction industry; 2) what are the underlying mechanisms through which visualisation technologies improve the effectiveness of training; 3) what issues and limitations are associated with the designs of training approaches.

RESULTS

Table 2 lists the analysis results for the nine publications. Due to the length limitation of the paper, only part of the results is summarised using the table while other results will be described in paragraphs. The results indicate that various technologies, including VR, AR, BIM, tracking technologies and game engines, have been utilised to support training. The application contexts ranged from risk/hazard identification (4 cases), assessing training processes (2 cases), training complex procedural tasks (1 case), warning workers of hazardous situations (1 case), and understanding safety implications of decisions and actions (1 case). The mechanisms underlying those training approaches are primarily related to the abilities of visualisation technologies in capturing and visualising real-world scenarios, providing rich information about site conditions and environment, and enabling workers to practice tasks or understand hazards inherent in work activities in a hazard-free environment.

All the publications also included an assessment/evaluation section to assess/evaluate the applicability of training systems or approaches. Most of the studies used the method of experiment (5 cases) in a controlled environment conducted with either trainees, professionals or graduate students, while the others (4 cases) invited participants to provide feedback or opinions. Almost all the publications reported promising or positive assessment/evaluation outcomes.

DISCUSSION

Despite the range of years for literature searching was specified to be almost two decades (i.e. 2000-2019), only nine publications were sourced from the databased relevant to the application of visualisation technologies in supporting safety training in construction. This, to certain extent, implies that the utilisation of visualisation technologies in safety training is still in the developmental stage, and there is great potential for further research into this area to achieve improved training outcomes. The application contexts for visualisation technologies primarily focused on improving individual capability in risk/hazard identification through virtual environments.

Table 2: Analysis results for the literature

Study	Technology	Safety aspect	Underlying mechanism
Azhar (2017)	Immersive virtual environments (Oculus Rift) - a light weight headset Convert a BIM model into VR environment	Hazards identification on construction site: • Unsafe use of forklifts • Inadequate fall protection • Electrical hazards • Falling objects • Tripping hazards	The project team members used the VR headset to view the created hazardous scenarios and provided their feedback.
Cheng and Teizer (2013)	Real-time location tracking sensors (Ultra-Wideband tags) and VR	Monitoring safety and activities among ironworker apprentices and trainees	Visualised training sessions by tracking real-time data; Close-call incidents were identified and converted to VR and replayed to the trainees and trainers; Provided feedback on mitigation
Goulding *et al.*, (2012)	Interactive VR environment	Safety implications of decision makings for construction offsite production	Developed scenario-based learning from a real site and visualised it in VR; Trainees made decisions and took actions based on different site scenarios; Trainees understood how different decisions/actions led to different consequences
Hou *et al.*, (2017)	Mixed reality (with AR and VR)	Procedural skills training in operating and maintaining oil and gas facilities	Trainees virtually interacted with a scenario tailored for specific task requirements and rehearses the task procedures; Such training systems could enhance trainees' visual-spatial, psychomotor and cognitive, and kinaesthetic capabilities
Kim *et al.*, (2017)	An image-based safety assessment system capturing safety information, which is visualised using AR in a wearable device	Construction site: to reduce struck-by accidents	The vision-based hazardous avoidance system helped workers to instinctively recognise hazardous situations and take proactive measures to avoid danger
Li *et al.*, (2012)	Game engine technology (Unity 3D) enabled visual safety assessment system (VSAS)	Workers' hazard identification and safety assessment relating to PPE	The virtual training approach provided rich information on site conditions, work behaviours and construction methods, and provides meaningful ways of assessment
Park and Kim (2013)	Safety management and visualization system (SMVS) that integrates BIM, location tracking, AR, and game technologies	Risk identification, workers' capacity of risk recognition, communication between managers and workers	The system as a safety education tool enabled worker to pre-experience activity-specific safety risks; improved safety communication between managers and workers
Perlman *et al.*, (2014)	Virtual reality	Hazard identification	VR enabled individuals to be present within hazardous conditions and identify workplace hazards
Teizer *et al.*, (2013)	Tracking system with Ultra-Wideband (UWB) location tracking technology	Safety performance in steel-erection training sessions	Visualising the training session by tracking real-time data helped to review the training process, assess the effectiveness of the training program and obtain feedback for improvement

However, apart from being able to recognise potential hazards in the work environment, construction workers also need to understand risks associated with their work tasks and perform the tasks adhering to safety requirements. A construction

project normally involves a large amount of work tasks and trade activities. This raises a concern that what tasks and activities are more suitable to be trained with visualization technologies, or to which extent virtualised training content can be generally used in multiple work tasks or activities. Future research can potentially develop a taxonomy identifying the applicability of different training approaches for different construction work tasks by considering the characteristics of work tasks.

The research results indicate that visualisation technologies are not only used for training purpose, but also used to assess the effectiveness of training through virtualising and then reviewing training sessions. The review process provides valuable feedback in terms of what improvements are required from trainees in their learning process and how trainers can better facilitate the training process. Future research can extend the application to assess another critical element of training, i.e. training transfer, which is defined the extent to which trainees apply the learned skills and knowledge in their actual work. Training does not result in improved safety and productivity performance if trainees do not transfer acquired skills and knowledge into work (Baldwin and Ford, 1988).

It seems that none of the studies has considered user/human factors when designing the virtualised training systems, such as the levels of skills (i.e. entry, advanced, and experienced), the level of familiarity with technologies and individual learning styles. Apart from considering technical issues (e.g. compatibility between technologies, the performance of display car), research may also need to consider personal factors to enhance the human-technology interactions.

Most of the assessment or evaluation processes in the publications were not robust enough. For example, some studies invited graduate students to participate in experiments in controlled environments, some did not involve a control group to compare results, while some invited professionals and workers to have a trail experience and provide qualitative feedback. It can be difficult to ascertain the real effectiveness of those training systems or approaches with such evaluation settings. Also, the participants involved in the evaluation can be different from actual trainees in terms of experience, skills, psychological factors, etc.

Although there is an abundance of safety training programs available in construction, there has been little investigation into the effectiveness of such programs (Tackett *et al.,* 2006). In the course of reviewing the literature on how visualisation technologies (e.g. VR and AR) may help to improve the quality of construction safety training comparing with the traditional classroom training, we reached a similar conclusion to Tackett *et al.,* (2006). The effectiveness of visualisation technologies' application in safety training hasn't been systematically evaluated against its learning outcomes. In addition, most of the VR and AR applications in safety training are limited to a single construction site with the main focus on enhancing hazard identification and disregards the possible variations on training needs in project life cycle, job types and human factors. To address these shortcomings, we developed the following framework based on the four-dimensional model of De Freitas and Neumann (2009) for future studies on the topic (Figure 1).

Drawing from the above framework in Figure 1, the application of visualisation technologies in safety training needs to firstly consider what people need to learn (context), how they learn it (Pedagogy), when they learn it (Learner), and where they learn it (Representation). Taking "job types" under context for example, it is likely

that iron workers need different safety training content compared to crane operators on the site.

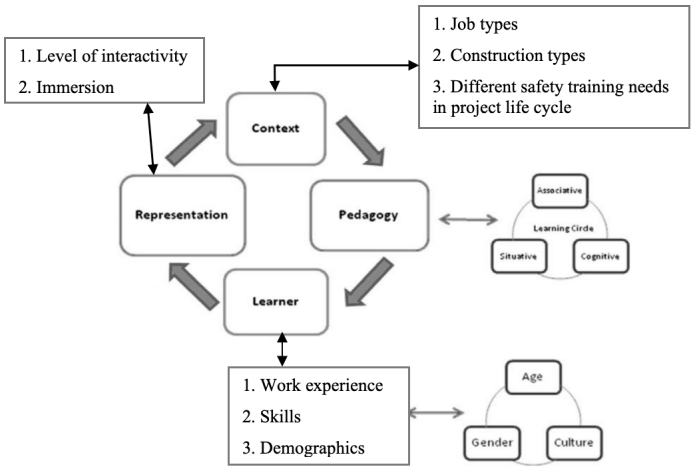


Figure 1: The four-dimensional framework

Different training content may require using different pedagogical methods: 1) Situative refers to supporting communities of practice; 2) Cognitive refers to building upon experience and reflection; and 3) Associative refers to giving immediate feedback. Different pedagogical methods will affect learners' experience. Based on learner's characteristics such as age, work experience and skills, the representation of visualisation technologies such as the level of interactivity and virtual reality could be vastly different. Finally, the effectiveness of the representation of visualisation technologies should be evaluated against the context.

CONCLUSION

This paper reports the preliminary findings from a pilot study using literature review. A literature searching was performed in the database of ScienceDirect within the range of years 2000-2019. Only nine studies were identified from this literature searching, indicating that the application of visualisation technologies in safety training is still in the early developmental stage. A further analysis of the literature indicates that existing applications of visualisation technologies have mainly focused on hazard identification and a few specific work tasks. Given a large amount of work tasks and trade activities involved in a construction project, it is unclear about what work tasks and activities are more suitable to be trained with visualisation technologies, or to which extent virtualised training content can be applied in multiple work tasks or activities. In addition, the development of visualisation technologies has not considered broader contextual factors (e.g. different work types, different training needs), pedagogy (e.g. theory of learning), and learners' characteristics (e.g. experience, skills), etc. This gap has led to the suggestion of a four-dimensional framework in this paper to provide directions for future research in application of visualisation technologies in safety training. A limitation associated with this paper is that only one database was used for the literature searching in this pilot study. A broader and more comprehensive literature review will be conducted to further understand the application of visualisation technologies in safety related training in future.

REFERENCES

Azhar, S (2017) Role of visualization technologies in safety planning and management at construction jobsites, *Procedia Engineering*, 171, 215-226.

Baldwin T T and Ford, J K (1988) Transfer of training: A review and directions for future research, *Personnel Psychology*, 41**,** 63-105.

Burke, M J, Sarpy, S A, Smith-Crowe, K, Chan-Serafin, S, Salvador, R O and Islam, G (2006) Relative effectiveness of worker safety and health training methods, *American Journal of Public Health*, 96(**2**), 315-324.

Cheng, T and Teizer, J (2013) Real-time resource location data collection and visualization technology for construction safety and activity monitoring applications, *Automation in Construction*, 34, 3-15.

De Freitas, S and Neumann, T (2009) The use of 'exploratory learning' for supporting immersive learning in virtual environments, *Computers and Education*, 52(**2**), 343-352.

Gheisari, M and Irizarry, J (2016) Investigating human and technological requirements for successful implementation of a BIM-based mobile augmented reality environment in facility management practices, *Facilities*, 34(**1/2**), 69-84.

Goulding, J, Nadim, W, Petridis, P and Alshawi, M (2012) Construction industry offsite production: A virtual reality interactive training environment prototype, *Advanced Engineering Informatics*, 26(**1**), 103-116.

Irizarry, J, Gheisari, M, Williams, G and Walker, B N (2013) InfoSPOT: A mobile Augmented Reality method for accessing building information through a situation awareness approach, *Automation in Construction*, 33, 11-23.

Ioannidis, J P, Greenland, S, Hlatky, M A, Khoury, M J, Macleod, M R, Moher, D and Tibshirani, R (2014) Increasing value and reducing waste in research design, conduct and analysis, *The Lancet*, 383(**9912**), 166-175.

Hallet, J, Soler, L, Diana, M, Mutter, D, Baumert, T F, Habersetzer, F and Pessaux, P (2015) Trans-thoracic minimally invasive liver resection guided by augmented reality, *Journal of the American College of Surgeons*, 220(**5**), 55-60.

Haslam, R A, Hide, S A, Gibb, A G F, Gyi, D E, Pavitt, T, Atkinson, S and Duff, A R (2005) Contributing factors in construction accidents, *Applied Ergonomics*, 36(**4**), 401-415.

Hou, L, Chi, H, Tarng, W, Chai, J, Panuwatwanich, K and Wang, X (2017) A framework of innovative learning for skill development in complex operational tasks, *Automation in Construction*, 83, 29-40.

Hou, L and Wang, X (2013) A study on the benefits of augmented reality in retaining working memory in assembly tasks: A focus on differences in gender, *Automation in Construction*, 32, 38-45.

Kim, K, Kim, H and Kim, H (2017) Image-based construction hazard avoidance system using augmented reality in wearable device, *Automation in Construction*, 83, 390-403.

Krasnyanskiy, M N, Ostroukh, A V, Karpushkin, S V, Dedov, D L and Obukhov, A D (2014) Design of simulators for automated information systems of engineers' training, *Journal of Applied Sciences*, 14(**21**), 2674-2684.

Li, H, Chan, G and Skitmore, M (2012) Visualizing safety assessment by integrating the use of game technology, *Automation in Construction*, 22, 498-505.

Palmarini, R, Erkoyuncu, J A, Roy, R and Torabmostaedi, H (2018) A systematic review of augmented reality applications in maintenance, *Robotics and Computer-Integrated Manufacturing,* 49, 215-228.

Park, C-S and Kim, H-J (2013) A framework for construction safety management and visualization system, *Automation in Construction*, 33, 95-103.

Perlman, A, Sacks, R and Barak, R (2014) Hazard recognition and risk perception in construction, *Safety Science*, 64, 22-31.

Ruwanpura, J Y, Hewage, K N and Silva, L (2012) Evolution of the i-Booth© onsite information management kiosk, *Automation in Construction*, 21, 52-63.

Safe Work Australia (2017) *Work-Related Traumatic Injury Fatalities, Australia 2017*. Canberra: Safe Work Australia.

Safe Work Australia (2015) *Construction Industry Profile*. Canberra: Safe Work Australia.

Safe Work Australia (2012) *Australian Work Health and Safety Strategy 2012-2022: Healthy, Safe and Productive Working Lives*. Canberra: Safe Work Australia.

Tackett, J, Goodrum, P M and Maloney, W F (2006) *Safety and Health Training in Construction in Kentucky.* Silver Spring, MD, USA: The Center to Protect Workers Rights.

Teizer, J, Cheng, T and Fang, Y (2013) Location tracking and data visualization technology to advance construction ironworkers' education and training in safety and productivity, *Automation in Construction*, 35, 53-68.

Wilkins, J R (2011) Construction workers' perceptions of health and safety training programmes, *Construction Management and Economics*, 29(**10**), 1017-1026.

Tsai, M-K, Lee, Y-C, Lu, C-H, Chen, M-H, Chou, T-Y and Yau, N-J (2012) Integrating geographical information and augmented reality techniques for mobile escape guidelines on nuclear accident sites, *Journal of Environmental Radioactivity*, 109, 36-44.

EXPLORING THE POTENTIAL IMPROVEMENT OF QUALITY CONTROL IN THE CONSTRUCTION INDUSTRY WITH THE USE OF DIGITAL TECHNOLOGY

Christopher Staples[1] and John Spillane[2]

[1] *Taylor Woodrow, VINCI Construction UK, Astral House, Imperial Way, Watford, Hertfordshire, WD24 4WW, UK*

[2] *School of Engineering, University of Limerick, Limerick, V94 T9PX, Ireland*

The construction industry has traditionally relied on paper to manage quality records, resulting in the capture and analysis of data being challenging, preventing historical performance analytics that lead to better outcomes. This research is aimed at critiquing the application of digital technologies for the potential improvement of quality management in the construction phase of civil engineering projects. To address the aim, two objectives emerge. The first is reviewing digital technologies that are available for use in quality control that could assist in the reduction of defects. The second is seeking the viewpoint from construction professionals to develop a quality management framework employing the most applicable digital technologies. In support of the objectives, a qualitative research approach involves multiple sources of data collection, gained from literature and interviews. Participants include digital engineering specialists, designers, main contractors and subcontractors. Applicable digital quality applications are identified as electronic document management systems, personal digital assistants, building information modelling (BIM), mobile construction application products (apps), clash mitigation using BIM, real time performance information, point clouds of as-built construction, three-dimensional vision on mobile phones and barcodes, among others. This holistic and collaborative approach facilitates personnel to make better decisions in the use of quality data. Implications for practice indicated that training, visible use of digital technologies and the provision of an effective common data environment are paramount in instigating digital applications. Employing this digital engineering in the construction phase should encourage the continuing journey to greater automation of the building activities themselves with an improvement in quality and productivity.

Keywords: digital technology, information management, total quality management

INTRODUCTION

The concept of quality assurance has arisen to ensure that customer requirements within a defined level of quality and conformance are achieved (Chan 1996). For the construction industry, digital technology in the form of computer aided design and building information modelling (BIM) has transformed design, however digital engineering is yet to be fully applied in processes concerning site quality within the ISO 9000 family of standards. Information and communication technology (ICT) are

[1] chris.staples@taylorwoodrow.com

Staples, C and Spillane, J (2019) Exploring the Potential Improvement of Quality Control in the Construction Industry with the Use of Digital Technology *In:* Gorse, C and Neilson, C J (Eds) *Proceedings of the 35th Annual ARCOM Conference,* 2-4 September 2019, Leeds, UK, Association of Researchers in Construction Management, 406-415.

changing working practices and this development has far reaching implications for construction firms, providing a new challenge in reconfiguring their resources for the new technological processes on large construction projects (Redwood *et al.,* 2017).

To address the potential improvement of quality assurance in the construction industry with the use of digital tools, two main elements emerge in this paper. The first is the review of digital technologies that are available to the construction infrastructure sector for use in the quality metric of performance. The second is seeking advice from construction professionals to develop a quality management framework, employing the most applicable digital technologies for the next 4 years from the initial appraisal.

Therefore, based on this premise, the aim is to undertake a comprehensive explorative analysis of the potential improvement of quality control in the construction phase, with the use of digital technology. This aim should reduce defects, increasing productivity and performance in an industry where the rework is in the region of 5% of total construction costs (Hwang *et al.,* 2009).

The associated literature reviewed, though covering various aspects within digital processes, fails to address the coherent improvement of quality through the application of current digital technology. Consequently, the principal questions in this research focus on the delivery of a digitally connected approach to the management of construction quality assurance to increase industry performance.

The construction industry still relies heavily on paper to manage its processes. Quality control is little different, with paper-based defects lists and quality records the norm. Due to the lack of digitisation, information sharing is delayed. Clients and contractors therefore often work in different versions of reality. The use of paper makes it difficult to apply historical performance analytics that leads to better outcomes (McKinsey 2016). Contractors are aware that inspection data can provide valuable information for constant improvement, but currently do not have processes for feeding back experience from inspections (Lundkvist *et al.,* 2010). To overcome these issues, the industry is beginning to deploy digital-collaboration and field-mobility solutions. This will result in the emergence of an ecosystem containing a digital layer, including blockchain, to manage large scale authentication and verification.

The 'Made Smarter Review', initiated by the United Kingdom Industrial Strategy Green Paper (Made Smarter 2017), promotes the utilisation of industrial digital technologies. Capital returns and quality should improve through increased accuracy and repeatability. Projects are increasingly being managed through online collaborative platforms (Cooper 2018). Such cloud solutions provide the basis for a 'digital ecosystem' with potentially large productivity benefits as construction firms increasingly utilise digital tools to improve company performance.

The ability to effectively process data with the extraction of useful insights has revolutionised society. With the commoditisation of the technology necessary for storing, computing, processing, analysing, and visualising phenomenon known as 'big data', there is immense interest in leveraging such technologies, for improving the efficiency of construction processes, such as quality control (Bilal *et al.,* 2016). Reductions in construction, operational and maintenance costs can be provided by building information modelling. Also, improved performance and quality can be achieved by effectively using this modelling data (Davila Delgado *et al.,* 2017), supporting informed decisions to produce effective actions. Additionally, the concept of BIM has risen rapidly in the field of construction engineering management (Li and

Yang 2017), with the term Level 3 being the collaboration between all disciplines using a single project model. BIM based intelligent site management models combining the internet, three-dimensional scanning, digital construction models, virtual reality and augmented reality are now possible (Yu *et al.,* 2019).

For the use of digital engineering in quality management, information technology (IT) in the form of document management systems is the enabler that links the various electronic processes together. The combination of processes provides valuable insights to achieve productivity improvements, by removing previously unnoticed impediments (Woodhead *et al.,* 2018). The standardisation of these processes between supply chain members is assisted by BS EN ISO 19650-2 that provides information management requirements in the delivery phase of assets (BS EN ISO 19650-2 2018).

The literature reviewed to improve quality assurance contains both methods that begin addressing the limitations of existing processes, and concepts that have not been widely implemented in business applications to further augment productivity. Progressing from the research articles identified, the applications providing increased surety of quality outcome that are not broadly adopted to date in the construction phase of civil engineering projects are listed in Table 1 below.

Reflecting on the literature, a large group of articles, for example, Lin *et al.,* (2016) and Akponeware and Adamu (2017) concentrate on the use of BIM for digital quality assurance, though this process is only one of the potential options available. Whereas Kwon *et al.,* (2014) considers the use of digital applications to reduce defects that bears on the final quality, pursuing the goal of executing a task correctly at the initial attempt. Chen and Kamara (2011) outlining the implementation of mobile computing in construction, note the increase in wireless network transfer speeds, has a great potential to improve on-site information management.

Regarding other papers, Park *et al.,* (2013) provide a highly technical ontology-based data collection template, but construction personnel on site are currently unfamiliar with this technique and yet to master the implementation. Chen and Luo (2014) propose a BIM based quality management model, that to be effective, requires direct field data transfer to the model. At present, this generally does not occur, and is unlikely to happen with the 4-year timeframe for application of digital processes in this research. Also, Dubas and Paslawski (2018) discuss methods for the elimination of construction quality issues with use of these digital solutions and Marsden (2019) provides a useful table of digital quality duties to achieve this aim.

In 'Understanding the Implications of Digitisation and Automation' (Oesterreich and Teuteberg 2016), the adoption of Industry 4.0 technologies has far-reaching implications for the whole construction industry, improving productivity, efficiency, quality and collaboration. To handle digital construction, projects need transformation into self-adaptive systems, to enable connections to align with project goals and configure the right workflow (Gangatheepan *et al.,* 2018).

In a case study of ICT innovation on a large hospital project the practicality of implementation is discussed (Davies and Harty 2013). Technical ICT skills are adopted into the construction project through personal relationships and arrangements. Execution is driven by construction project employees, rather than centrally by corporate IT.

Digital Process	Literature/Vendors	Comments
IT enabler / doc management system	BS EN ISO 19650-2 2018	agreement before site works
Personal digital assistant	Chen & Kamara 2011	education & training
Building information modelling	Lin et al 2016	using information element
Mobile & web applications	www.viewpoint.com	cope with high data traffic
Digital inspection & test plan	BIM360 2019	direct link to IT enabler
Clash mitigation using BIM	Akponeware & Adamu 2017	all contractors on one model
Real time performance information	Wang et al 2015	automated site performance
Mixed reality (digital & real)	Kwon et al 2014	vulnerable site equipment
3-dimensional (3D) vision to mobile	www.structure.io	for less exacting site use
Point clouds of as-built work	www.clearedge3d.com	set of data points in 3D
Sensors within manufacture	Akinci et al 2006	if only used once costly
Condition based monitoring	www.pix4d.com	need suitable vantage points
3D geological models	www.leapfrog3d.com	good as information input
Character rigging & animation	www.mixamo.com	more for method statements
Business intelligence	Batrinca & Treleaven 2015	gauge value from site trial
Radio frequency identification	Wang 2008	quality and production data
Photogrammetric vision	Fathi et al 2015	occlusion from obstacles
Machine vision	www.machinevision.co.uk	more for off-site factories
Simultaneous localisation & mapping	Cadena et al 2016	autonomous vehicles issue
1D & 2D barcodes	Chang et al 2013	suitable data connection
Automated construction plant	www.komatsu.com.au	search 'smart construction'
Mobile mapping platform	www.leica-geosystems.com	'mobile sensor platforms'

Table 1: Possible Digital Quality Management Processes

METHOD

For this paper, the qualitative research uses a relativist approach, whereby the views of participants are used to discover the appropriate digital applications for construction phase quality assurance. The qualitative research involves multiple sources of data collection gained from literature and semi-structured interviews. This is followed by analysing the data, to provide a quality management framework of the most applicable technologies. The research gathers information by asking participants to answer open ended questions (Flick 2009). Participants are chosen from designers, main contractors, subcontractors and specialists in digital engineering, of which 25 participants in total contribute to this study. The criteria for selection are also based on knowledge and experience of construction management and quality assurance. The same questions are asked to all interviewees, to obtain measurable data for further investigation. The meetings are transcribed, to ensure accurate records are available for analysis of the data. From the responses received, the research seeks broad patterns and themes.

The output from the direct questions in the interviews are tabulated, to discover the most appropriate digital quality technologies recorded. For other elements of the research, qualitative data analysis coding is carried out, to seek structure to recorded observations. Specific codes for types of participant responses are developed and the resultant data is quantitively organised, with this approach providing a means to introduce interpretations into the qualitative research methodology. Then in the same spreadsheet as for the direct questions, a series of tables present insights from data received, utilising the coded groups of topics from text transcripts. The most popular

processes chosen by the interviewees, are presented in the following Findings and Discussion section. In the same section, the implications of this research to infrastructure projects and construction management are considered. The research criteria principally involve civil engineering projects in the United Kingdom of over £50 million expenditure with a typical programme length of 4 years.

FINDINGS AND DISCUSSION

In Table 2, where the results of the qualitative analysis are presented, 'widely' is considered applications applied in projects by more than 75% of interviewees and 'localised' implementation by more than 50% of interviewees.

Table 2: Digital Engineering Applications

Digital Engineering Application	Widely	Localised	Comment
Information technology enabler	x		common data environment needed
Mobile / tablet as personal digital assistant	x		digitally co-operative site system
Building information modelling	x		little used for quality assurance
Mobile and web applications	x		choice of propriety systems
Digital inspection and test plan (ITP)		x	moves digital engineering forward
Clash mitigation using BIM	x		integration subcontractors' models
Real time performance data	x		as now used in earthworks
Point clouds of as-built work	x		uses light detection & ranging
Precise 3D vision to mobile phone	x		indoor mapping, 3D scanning
Condition based monitoring		x	often better for progress reports
3D geological models		x	underground utility avoidance
Radio frequency identification		x	cost of units to be considered
Photogrammetric vision		x	fusion photos & computer vision
1D and 2D barcodes	x		common for plant identification
Mobile mapping platform		x	use on backpack or drone

The findings of the research from interviewees responses are as follows:

5. The practical applications for site use dependent on developments by vendors who provide products in a simpler format than implied by academic papers. Tier 1 main contractors should work collaboratively with vendors to provide systems in a common data environment with trials of new products on site.
6. The project management plans followed equally by BS EN ISO 19650-2, specific digital engineering plans and digital inspection and test plans are typically the core procedures that act as the starting points to bind the quality assurance data together. Participants from Tier 2 subcontractors appreciate that Tier 1 contractors decide the management plans for each project.
7. To be visible in an electronic format with a connectivity empowered by technology, the data is enabled by a document management system though interface issues exist between legacy systems that current common data platforms only partly resolve.
8. The training and encouragement of site teams including subcontractors in the use of digital technologies is as important as the actual applications themselves. Interviewees were conscious that an awareness of BIM encouraged the use of other digital applications.
9. Though each application has benefits, the real advantage is utilising the data provided in a holistic and collaborative approach across surveying, geographic

information systems, BIM, automation, collaboration, business intelligence and digital mobility. This enables teams to anticipate issues from data and learning, preventing defects occurring by exchanging expertise.

10. Processes being witnessed in use at site level enables personnel to appreciate the benefits of these applications, with a project based digital champion to promote the unfamiliar technologies so that over a time the body of knowledge increases across the industry.

In the synthesis with the literature reviewed, Leung *et al.,* (2008) approach the improvement of quality using real-time communications, by effectively monitoring projects via cameras, providing progress data so that the supply chain can communicate remotely on issues which if unresolved result in defects. In Table 2 containing digital engineering applications, certainly condition-based monitoring, utilising cameras on tower cranes, is following this approach. Hou *et al.,* (2014) in the use of digital technologies for productivity improvement, take advantage of ICT, Radio Frequency Identification (RFID), laser scanning, BIM and augmented reality, with these processes supported by interviewees who are directly involved with site digital technology. The interviewees concur with Wang and Chong (2015), who state that BIM in the construction phase can improve project performance, though it must be integrated with other technologies. Kim *et al.,* (2008) employ personal digital assistants and a wireless web-integrated system for quality inspections. This system is favoured by all participants in this study. Wang *et al.,* (2015) propose integrating BIM and Light Detection and Ranging (LiDAR) for real-time quality control and Wang (2008) recommends enhancing construction quality inspection and management using RFID technology. Both proposals received favourable responses from interviewees.

For a critique of the research, by reflecting both on the literature studied and the transcribed data of the interviewees' conversations, the following is noted:

- Overall impression arises that the on-going process of digitalisation for quality records is irreversible including following facilities management operations.
- Published literature effectively explains and separately promotes the various elements of digital quality control, without providing a co-ordinated project assurance framework embracing all available processes.
- Successful implementation at project level depends on the management of change, as much as the applications themselves.
- Unfortunately, an excellent digital quality assurance process may still involve much rework, if the performance of the workforce in the subcontract packages deteriorates, then leading to a lower return on contractors' capital.
- Participants cautious on the positive outcomes, as concerns exist about other aspects of the industry, such as competitive tendering, encouraging under-resourced contractors, with insufficient fully agreed design information at time of construction with consequent loss of productivity.

From this research for the digital era, the new definition of quality assurance is less about the traditional adherence to drawings and specification, but now conformance to the data within a digital model that is the twin of the physical structure.

The implications for the potential improvement of quality control are as follows:

1 A variety of digitals applications that have matured over many years are available from individual vendors. These technologies operate quite satisfactorily, applying the process is now the issue. The way IT infrastructure

is set up and managed is what makes these digital applications useful, currently these systems on various electronic platforms are not necessarily compatible with each other. The evolution of data consumption is leading towards streaming latest information received on one platform.

2 Within this linked database approach sits the improvement of quality assurance on a project by digital methods. A robust system that ensures successful step by step operations can be created for project teams. Including specific digital processes, in the subcontract requirements for the supply chain, aids instigation. Once a common database is achieved, with Tier 1 and 2 contractor IT requirements in the conditions of contract, then personnel can understand how processes are performing. Also, broken chains where clients and contractors are using different platforms are prevented.

3 For the application of digital processes, competency of use is paramount, consequently suitable education at school and university is required. This occurs alongside company training particularly at a project commencement, to bring both employees and the supply chain on board. As digital applications are at an early stage of implementation on site, initially important for personnel to become familiar by using tablets and mobile phones. It is noted that IT appears very persuasive on a computer screen, accordingly the project team must be capable of providing resilient quality information.

4 Place personnel psychologically in charge of the technology, so there is a sense of owning the process and then encouraging a proactive awareness of digital quality processes. Though concerns exist that will all enterprises willingly take on board these digital processes, or will they have to be coerced into adopting them, especially to gain benefits that accrue from all parties co-operating across a common platform?

5 Digital quality control utilising a geographic information system (GIS) is very close to fruition. Earthworks operations already put this concept into limited practice. It is considered that surveying processes will incur largest change during next decade with a 3D approach to drawings becoming the norm.

6 For effective utilisation in the construction phase, the I (information) in BIM needs to be readily available besides the model. Any study that enhances this information aspect would be advantageous for construction management teams as clients are becoming aware of the benefit of digitally tracking quality.

CONCLUSION

Digital engineering technology is a holistic and collaborative approach that empowers construction management personnel to make better decisions with data. The connected tactic to better information management is delivered through harnessing the specialist technologies and capabilities of business intelligence, BIM, surveying, geographic information systems, automation, collaboration and digital mobility. Within this linked approach sits the improvement of quality assurance on a project by digital methods. Note BIM is one component of this improvement process.

These digital methods for quality assurance are yet to be fully provided in a common data environment. As well, implementation is at an early stage of development. In the most appropriate digital quality engineering applications (Table 2) chosen by interviewees for instigation on site, most are currently only used by specialist departments. Albeit a variety of digital quality applications that have matured over many years are available from vendors. The technology operates quite satisfactorily,

with the published literature tending to analysis separately the various elements supporting this premise, applying the co-ordinated processes is now the challenge.

There are construction processes, such as earthworks, incorporating geo-spatial setting out, already providing improved quality control, utilising digital technology. For both main contractors and subcontractors, the primary goal is presently for staff and operatives becoming familiar with the world of this technology, then using smartphones or tablets to record and transmit the quality data. Particularly at a project's commencement, training actively supported by senior management, is required to bring both employees and the supply chain on board.

The application of digital engineering to quality issues is not only a choice of systems, but also the suitability of IT infrastructure and the body of technical knowledge available in the construction industry. The evolution of data consumption is leading towards streaming the latest information received. The way IT is set up and managed is the enabler, making digital applications useful. Also, once a common database is achieved within Tier 1 and 2 contractor IT outputs and specified in the conditions of contract, then the overall project team can readily understand how quality processes are performing. Consequently, broken chains, where clients and contractors are using different electronic platforms, cumulating in poor communication are prevented.

For academia, the review and enhancement of current education with a feed-back loop to industry encourages the successful promotion of digital technology. The I (information) in BIM needs to be readily available for quality applications during the construction phase. Any study that enhances this information aspect would be very helpful. Also, research should be carried to test the extent to which all these technologies commercially match or improve on the current levels of accuracy for quality control.

The expansion of knowledge from this paper involves four key contributions:

- Awareness of digital quality technology for quality control.
- Provides project teams a quality management framework of digital processes.
- Senior management benefit from the research findings when setting up digital quality assurance systems to assist the improvement of company performance.
- Enabling the journey of digital engineering in the construction phase.

To conclude, digital applications such as 3D models are already prevalent for design. Shortly the growing use of digital technology for quality assurance in civil engineering infrastructure projects will take place, as indicated by the views of the participants. It emerged that facilities management operations are increasingly using digital systems. So, expanding digital engineering research for the actual building works, encourages the automation for the outstanding element of the construction process that to date been unaffected by the recent march of automated technology in other industries, providing improved quality, productivity and return on investment.

REFERENCES

Akinci, B, Boukamp, F, Gordon, C, Huber, D, Lyons, C and Park, K (2006) Formalism for utilization of sensor systems and integrated project models for active construction quality control, *Automation in Construction*, 15, 124-138.

Akponeware, A and Adamu, Z (2017) Clash detection or clash avoidance? An investigation into coordination problems in 3D BIM, *MDPI Buildings*, 8(**3**), Article 75.

Batrinca, B and Treleaven, P (2015) Social media analytics: A survey of techniques, tools and platforms, *AI and Society*, 30, 89-116.

Bilal, M, Oyedele, L, Qadir, J, Munir, K, Ajayi, S, Akinade, O, Owolabi, H, Alaka, H and Pasha, M (2016) Big data in the construction industry: A review of present status, opportunities and future trends, *Advanced Engineering Informatics*, 30, 500-521.

BIM360 (2019) *Quality Management.* https://bim360.autodesk.com/construction-management-software/quality-management [Accessed 18 February 2019]

BS EN ISO 19650-2 (2018) *BIM Information Management Requirements in the Delivery Phase of Assets*. https://shop.bsigroup.com/ProductDetail?pid=000000000030389654 [Accessed 20 May 2019]

Cadena, C, Carlone, L, Carrillo, H, Latif, Y, Scaramuzza, D, Neira, J, Reid, I and Leonard, J (2016) Past, present and future of simultaneous localization and mapping, *Institute of Electrical and Electronics Engineers: Transactions on Robotics*, 32, 1309-1332.

Chan, P C (1996) *Quality Assurance in the Construction Industry*, *Architectural Science Review*, 39(2), 107-112.

Chang, J, Su, Y and Lin, Y (2013) Development of mobile BIM assisted defect management system for quality inspection of building projects, *In*: *Proceedings of the 13th East Asia-Pacific Conference on Structural Engineering and Construction*, 11-13 September, Sapporo, Japan.

Chen, L and Luo, H (2014) BIM-based construction quality management model and its applications, *Automation in Construction*, 46, 64-73.

Chen, Y and Kamara, J (2011) A framework for using mobile computing for information management on construction sites, *Automation in Construction*, 20, 776-788.

Cooper, S (2018) Civil engineering collaborative digital platforms underpin the creation of digital ecosystems, *Institution of Civil Engineering Proceedings*, 171, 14.

Davies, D. and Harty, C (2013) Implementing site BIM: A case study of ICT innovation on a large hospital project, *Automation in Construction*, 30, 15-24.

Davila Delgado, M, Butler, L, Gibbons, N, Brilakis, I, Elshafie, M and Middleton, C (2017) Management of structural monitoring data of bridges using BIM, *Institution of Civil Engineering Proceedings*, 170(**3**) 204-218.

Dubas, S and Paslawski, J (2018) Methods of construction quality issues elimination with use of modern technology, *MATEC Web of Conferences*, 222, article 01001.

Fathi, H, Dai, F and Lourakis, M (2015) Automated as-built 3D reconstruction of civil infrastructure using computer vision, *Advanced Engineering Informatics*, 29, 149-161.

Flick, U (2009) *An Introduction to Qualitative Research 4th Edition.* London: Sage.

Gangatheepan, S, Thurairajah, N and Lees, M (2017) *Learning Ecology for Digital Transformation in Construction Projects*, ARCOM Compendium of Working Papers 2017. Available from http://www.arcom.ac.uk/-docs/archive/2017-Working-Papers.pdf, 32-41.

Hou, L, Wang, X, Wang, J and Truijens, M (2014) Integration framework of advanced technologies for productivity improvement for LNG mega-projects, *Journal of Information Technology in Construction*, 19, 360-382.

Hwang, B, Thomas, S, Hass, C and Caldas, C (2009) Measuring the impact of rework on construction cost performance, *Journal of Construction Engineering and Management*, 135(**3**).

Kim, Y, Oh, S, Cho, Y and Seo, J (2008) PDA and wireless web-integrated system for quality inspection and defect management of apartment housing projects, *Automation in Construction*, 17(**2**), 163-179.

Kwon, O, Park, C and Lim, C (2014.) Defect management system for reinforced concrete work utilising BIM, image-matching and augmented reality, *Automation in Construction*, 46, 74-81.

Leung, S, Mak, S and Lee, B (2008) Using a real-time integrated communication system to monitor the progress and quality, *Automation in Construction*, 17(**6**), 749-757.

Li, J. and Yang, H (2017) *Research on Development of Construction Industrialization Based on BIM Technology Under the Background of Industry 4 0*, *MATEC Web of Conferences*, 100, article 02046.

Lin, Y, Chang, J and Su, Y (2016) Developing construction defect management system using BIM, *Journal of Civil Engineering and Management*, 22(**7**) 903-914.

Lundkvist, R, Meiling, J and Vennström, A (2010) Digitalization of inspection data: A means for enhancing learning and continuous improvements? *In*: Egbu, C (Ed.), *Proceedings 26th Annual ARCOM Conference*, 6-8 September 2010, Leeds, UK. Association of Researchers in Construction Management, Vol. 2, 829-838.

Made Smarter (2017) *Made Smarter Review 2017*. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/655570/20171027_MadeSmarter_FINAL_DIGITAL.pdf [Accessed 18 February 2019]

Marsden, P (2019) *Digital Quality Management in Construction*. Abingdon: Routledge.

McKinsey (2016) *Imagining Construction's Digital Future*. https://www.mckinsey.com/industries/capital-projects-and-infrastructure/our-insights/imagining-constructions-digital-future [Accessed 18 February 2019]

Oesterreich, T and Teuteberg, F (2016) Understanding the implications of digitisation and automation in the context of Industry 4 0: A triangulation approach and elements of a research agenda for the construction industry, *Computers in Industry*, 83, 121-139.

Park, C, Lee, D, Kwon, O and Wang, X (2013) A framework for proactive construction defect management using BIM, augmented reality and ontology-based data collection template, *Automation in Construction*, 33, 61-71.

Redwood, J, Thelning, S, Elmualim, A and Pullen, S (2017) The proliferation of ICT and digital technology systems and their Influence on the dynamic capabilities of construction firms, *Procedia Engineering*, 180, 804-811.

Wang, J, Sun, W, Shou, W, Wang, X, Wu, C, Chong, H, Liu, Y and Sun, C (2015) Integrating BIM and LiDAR for quality control, *Intelligent Robot Systems*, 79, 417-432.

Wang, L (2008) Enhancing construction quality inspection and management using RFID technology, *Automation in Construction*, 17, 467-47.

Wang, X and Chong, H (2015) Setting new trends of integrated Building Information Modelling (BIM) for construction industry, *Construction Innovation*, 15(**1**), 2-6.

Woodhead, R, Stephenson, P and Morrey, D (2018) Digital construction: From point solutions to IoT ecosystem, *Automation in Construction*, 93, 35-46.

Yu, Z, Peng, H, Zeng, X, Sofi, M, Xing, H and Zhou, Z (2019) Smarter Construction Site Management using the latest information technology, *Institution of Civil Engineering Proceedings*, 172(**2**) 89-95.

THE POTENTIAL OF DIGITAL TECHNOLOGY TO IMPROVE CONSTRUCTION PRODUCTIVITY

Upeksha Hansini Madanayake[1] and Mustafa Selçuk Çıdık

School of the Built Environment and Architecture, London South Bank University, 103 Borough Road, London, SE1 0AA, UK

Despite increasing adoption of digital technology in construction, productivity reports have remained disappointing. To develop insights into the reasons of this contradiction, the present paper suggests drawing on organisational competitiveness literature considering that the factors-affecting-productivity are conveniently captured within that literature. Through a questionnaire survey, the paper analyses the views of managers in the UK construction industry regarding the effect of Building Information Modelling (BIM) and Big Data Analytics (BDA) on organisational competitiveness. The results are then traced back to the factors-affecting-productivity for discussion. It is concluded that digitalisation enables performance improvements that can be tied to productivity gains, but this relies on the presence of certain skills and knowledge, which require training. It is also concluded that the lack of impact of digitalisation on some of the factors-affecting-productivity may be limiting the impact of digitalisation on the overall productivity, thus leading to a stagnating productivity.

Keywords: big data, BIM, competitiveness, digital technology, productivity

INTRODUCTION

Construction productivity has been reported as stagnating worldwide for several decades against the backdrop of an overall productivity growth in global economy (García de Soto *et al.,* 2018). While the construction industry has been repeatedly reported to be under-performing in terms of productivity, there has also been a growing trend of digitalisation that is fuelled by the argument that digital technologies improve the practices in construction (Zhan *et al.,* 2018). Motivated by this contradiction, the present paper questions the statement that construction productivity has not been improving over the last several decades.

To this end, the paper first identifies four broad categories of factors-affecting-productivity in construction through a review of the literature. These are (1) people, (2) logistics and operations, (3) communication and information management, and (4) regulative framework. The four categories together suggest that the impact of digitalisation on productivity must be studied as a complex and multi-faceted (i.e. organisational) phenomenon. Hence, through a review of the organisational competitiveness literature, the paper makes the case that analysing the impact of digitalisation on organisational competitiveness can help revealing the complex picture of how digitalisation effect on productivity. Building upon this argument, the paper presents the results of a questionnaire survey that draws upon organisational

[1] madanayu@lsbu.ac.uk

Madanayake, U H and Çıdık, M S (2019) The Potential of Digital Technology to Improve Construction Productivity *In:* Gorse, C and Neilson, C J (Eds) *Proceedings of the 35th Annual ARCOM Conference,* 2-4 September 2019, Leeds, UK, Association of Researchers in Construction Management, 416-425.

competitiveness literature to measure the level of enhancement achieved by the use of Building Information Modelling (BIM) and Big Data Analytics (BDA). In discussion section, the results of the survey are traced back to the initially identified categories of factors-affecting-productivity, thus developing insights into whether and how/where the expected productivity benefits of digitalisation accrue in practice. As a result, the paper informs the debate around construction productivity and scrutinises the argument that construction productivity has not improved over the last several decades. It shows that digitalisation can be tied to productivity gains in case skills and knowledge essential to exploit digital technologies as an organisation are in place.

Productivity and Organisational Competitiveness

As stated by Brynjolfsson and Hitt (1998), productivity is a simple concept: it is the amount of output produced per unit of input. However, a review of the literature on the factors-affecting-productivity reveals that productivity is the result of several interdependent components working together (see Table 1). This suggests that the impact of digitalisation on productivity must be studied as complex and multi-faceted (i.e. organisational) phenomenon.

Table 1: Summary of Factors Affecting Construction Productivity

Factors Affecting Construction Productivity	Category	Author(s)
Skills shortage; labour training and upskilling; leadership	People	Hasan *et al.,* 2018; Caldas and Gupta 2017; Lindhard and Larsen 2016; Böhme *et al.,* 2018
Unavailability of materials, proper tools, and equipment; unexpected materials; resource misallocation; inadequate risk assessment and mitigation, lack of supervision of operations; lack of labour supervision	Logistics and Operations	Hasan *et al.,* 2018; Abdul Kadir *et al.,* 2005; Kenley 2014; Naoum 2016; Zhan *et al.,* 2018; Khosrowshahi and Arayici 2012
Collaboration and coordination; stakeholder communication and coordination; communication of shared objectives; human-related delays in responding to requests for information	Communication and Information Management	Hasan *et al.,* 2018; Aziz *et al.,* 2013; Jarkas and Bitar 2011; Lindhard and Larsen 2016; El-Gohary and Aziz 2014; Makulsawatudom and Emsley 2004
Transparent policies, lack of certainty and continuity of work, compliance with standards, jurisdictional complexities, delays in permissions and permits, implementation of health, safety and environmental policies	Regulative Framework	Lindhard and Larsen 2016; Dai *et al.,* 2009; Aziz *et al.,* 2013; Matusik and Mickel 2011; Jarkas and Bitar 2011

The four categories of factors-affecting-productivity (see Table 1) are conveniently captured in organisational competitiveness literature (e.g. Porter 1985), thus suggesting that an analysis of the impact of digitalisation on organisational competitiveness can be traced back to understand the complex picture of how digitalisation affect productivity. Therefore, the remaining part of this section focuses on 'organisational competitiveness' to discuss the link between each of the four categories of factors-affecting-productivity and organisational competitiveness with references to the impact of digital technology.

People

'People' is widely acknowledged as an important determinant of organisational competitiveness in construction management literature. Lu (2006) claims that the workforce of a company is one of the greatest assets that create value for an organisation. Henricsson *et al.,* (2004) define a competitive organisation as the one with 'satisfied employees' claiming that satisfaction motivates employees to continuously contribute to an organisation. Further, Ericsson *et al.,* (2005) who

discusses about a Total Value Competitiveness framework stresses that 'management skills' are critical determinants for organisational competitiveness, thus emphasising the importance of 'people'. The authors further specify the importance of institutions for training and development, thus pointing out to the criticality of investing in 'people'. Previous research also reported on the intersection of digital technology, people and competitiveness. Ross (1996), for example, shows how digital technology help enhancing firms' competitiveness by improving worker satisfaction; as innovative IT technologies could make day-to-day tasks more convenient while introducing them to new areas for training and development. Moreover, according to Betts *et al.,* (1991) when strategically approached, digital technology can be an enabling mechanism for the upskilling of employees. On the other hand, Harty *et al.,* (2007) claimed that evolving technology means shifted training and education requirements in construction, and that the different interpretations of the changing training and education needs would create people with different capabilities.

Logistics and Operations

The significance of 'logistics and operations' in an organisation is recognised in the organisational competitiveness literature. Henricsson *et al.,* (2004) point out that, in construction, management processes can be commercialized to be turned into improved performance leading to competitive advantage. This resonates with Buckley *et al.,* (1988) who noted that definitions and measures of competitiveness vary, and could distinguish three different views of competitiveness: the ability to perform well in terms of effectiveness (quality) and efficiency (speed) the endowment of assets (plant, material), and the ability to predict the future performance. Ericsson *et al.,* (2005) who examined the Total Value Competitiveness (TVC) framework acknowledged that 'technological ability' is a key when appraising the TVC. Further, Barney (1991) who analysed firm's opportunities and threats in its competitive environment referred organisational competitive advantage as a 'collection of resources' consisting of plant, material and equipment. Harty *et al.,* (2007) suggests that radical as well as incremental innovation has the potential to increase the competitiveness of a construction industry and show that research and development to increase 'innovation capability' has been mentioned in a number of competitiveness studies. Over the past decades, there has been no shortage of studies on organisational competitiveness focusing on the impact of digitalisation to logistics and operations. The use of information technology in construction is extending beyond the stage of piecemeal application for improving the daily-basis operational efficiency of discrete logistics and operations in individual organisations (Betts *et al.,* 1991). Singh *et al.,* (2011) assert that innovative IT solutions like BIM has the potential to profoundly change how construction is operated by stimulating the efficiency and effectiveness of information sharing among project stakeholders for the ease of logistics. Betts *et al.,* (1991) stresses that when the changes are managed carefully, IT significantly impacts on construction business.

Communication and Information Management

Research on organisational competitiveness in construction shows the importance of 'communication and information management'. Harty *et al.,* (2007) identify that having an 'information management system' and the 'ease of information abstraction' provides organisational competitive advantage as it supports well-informed and effective decisions. Wei *et al.,* (2010) studies the influence of information and communication capabilities for sustainable competitive advantage and identifies

communication and information management as a determinant of competitive advantage due to their positive impact on efficiency. Further, based on the resources-based view of competitiveness, Bharadwaj (2000) affirms that, if information processing is integrated with other resources in an organisation, then an organisation could achieve time reductions and faster decision making, thus gaining competitive advantage. Several studies have outlined the benefits that construction organisations could achieve by using digital technology for 'communication and information management'. Betts *et al.,* (1991) explain that strategic application of digital technology ensures that information can be effectively exploited by the users, thus enabling effective decision-making. Singh *et al.,* (2011) examine organisations that use digital technology and affirm that such organisations could expand and diversify their activities in several different ways, thus leading to faster and better decisions due to better communication and information management. Additionally, BIM literature is abundant with studies claiming various benefits of 'communication and information management' that increase competitiveness (e.g. Grilo and Jardim-Goncalves 2010).

Regulative Framework

A rightly tailored regulative framework, which governs and enables the organisation to conceive of and implement strategies, is likely to improve performance efficiency and effectiveness for competitive advantage (Betts *et al.,* 1991). The literature lists several attributes related to regulative framework that are important for enabling sustainable competitive advantage. For the purposes of this paper, such attributes can be conveniently classified into two: strategic governance (Betts and Ofori 1992) and collaborative partnering (Harty *et al.,* 2007). The extent to which digital technology intersects with the organisational regulative framework depends on the ways in which technology is used in an organisation (Betts *et al.,* 1991). Lu (2006) suggests that using digital technology in construction organisations leads to improvements in collaboration and co-ordination by enabling the contractors to develop effective executional frameworks with right business partners as well as allowing smaller contractors to compete against larger ones. On the other hand, Çıdık *et al.,* (2017) warn that digital technology may impose new ways of working on practitioners that might hamper collaboration. Additionally, contractual challenges of working with BIM is acknowledged in literature (e.g. Porwal and Hewage 2013).

METHODOLOGY

A review of organisational competitiveness literature revealed that (i) the four categories of factors-affecting-productivity have also been acknowledged as areas of critical importance for organisational competitiveness, and (ii) digital technology can have positive impact on these areas. Hence, insights from organisational competitiveness literature are used to develop a questionnaire survey to understand whether, and to what extent, organisational competitiveness has been affected by using BIM and BDA in terms of the issues relating to (1) people, (2) logistics and operations, (3) communication and information management, and (4) regulative framework. Inquiring into the impact of digital technology on competitive advantage through these four areas enables a rich discussion of how productivity might be affected by digitalisation as a result of complex interdependencies between different categories of factors-affecting-productivity.

The respondents of the questionnaire were chosen through a non-random purposive sampling effort. The respondents involved practitioners occupying managerial roles at various levels in the UK construction companies using BIM and/or BDA. The

analysis follows a two-fold strategy. First, the enhancements relating to competitiveness as a result of using BIM and BDA are measured. Thus, the questionnaire asked its respondents to rate the level of enhancement achieved in each of criteria relating to the areas of 1) people, (2) logistics and operations, (3) communication and information management, and (4) regulative framework. A Likert scale was used in the questionnaire with a scale from 1 to 5 representing various levels of enhancement. Second, using a 4-point Likert scale, the respondents were asked to identify the level of importance of the skills and knowledge that are reported to be key for the exploitation of BIM and BDA by the literature. So, the second part of the analysis explored what skills and knowledge are essential in realising the claimed enhancements measured in the first part of the analysis. The second part also asked about the need for training on these essential skills and knowledge, now, and in five years. Thus, the second part of the analysis does not only reveal the skills and knowledge needed for addressing productivity issues through digitalisation but also reveals the practitioners' view about where the needs for training currently are, and where they are likely to be in five years.

ANALYSIS AND RESULTS

173 questionnaire forms were distributed. 63 usable responses were received which gives an average of 36.42% response rate for both BIM and BDA. Descriptive statistics were used to present the 'level of enhancement' of each criterion (see Table 2) alongside the mean and standard deviation of the answers. To measure respondents' perception on the level of enhancement for each criterion, the level of enhancement Index (LEI) formula was used (see Equation 1). The equation was derived from a similar formula computed by Chan and Kumaraswamy (2001).

$$LEI = \frac{5(n5) + 4(n4) + 3(n3) + 2(n2) + 1(n1)}{5(n1 + n2 + n3 + n4 + n5)} \quad \text{.... Equation (1)}$$

In this formula, n1, n2, n3, etc. refer to the total number of respondents who selected the corresponding rating in the Likert scale which ranges from 1 to 5. For example, n1 refers to the number of respondents who selected '1' in the Likert scale. The number of responses received for each number in the Likert scale are added-up, and then divided to the maximum possible value that could be achieved if all respondents gave a rating of '5'. When a question is not asked for BIM or BDA, this is indicated as 'not applicable' (N/A) in Table 2. Adopting the same formula, Table 3 shows the Degree of Importance (DII) of the skills and knowledge that managers need to possess to achieve enhancements in criteria listed in Table 2.

DISCUSSION

The results presented in Table 2 can be discussed from three perspectives: first in terms of the levels of enhancement in different categories, second in terms of the levels of enhancements of different criteria under a same category, and third in terms of the comparison of LEIs measured for BIM and BDA for a same criterion. Between the categories, the highest level of enhancement is measured in 'Communication and Information Management' due to BIM use (88.63% average LEI). This is in line with the dominant argument of BIM literature which suggests that BIM prevents the issues with unstructured and missing data that leads to productivity loss (El-Gohary and Aziz 2014). A similar high LEI is measured for the criterion measured only for BDA under this category suggesting that better insights into data improves communication and

information management. However, when all categories considered together it is clear that there are mixed levels of enhancements caused by BIM and BDA.

Table 2: Level of enhancement in organisational competitiveness criteria

#	Criteria	Mean		Std. Deviation		LEI %	
		BIM	BDA	BIM	BDA	BIM	BDA
	PEOPLE						
1	Employee satisfaction / retention	3.22	3.34	0.75	0.69	66.27	66.88
2	Professional skills and judgement	3.53	3.47	0.64	0.56	70.59	69.38
3	Training and education processes	3.75	3.53	0.88	0.71	74.90	70.63
	LOGISTICS and OPERATIONS						
4	Research and development for innovation	3.25	3.31	0.84	0.63	65.10	66.25
5	Technological capability	3.67	3.75	0.70	0.66	73.33	75.00
6	Effectiveness of plant and materials	3.82	3.66	0.90	0.89	76.47	73.13
7	Speed and quality of delivery	4.78	4.78	0.50	0.41	95.69	95.63
8	Performance predictability	4.82	4.78	0.43	0.41	96.47	95.63
	COMMUNICATION and INFORM. MAN.						
9	Less rework and time due to early risk detection	4.29	N/A	0.77	N/A	85.88	N/A
10	Ease of creating and managing information	4.48	N/A	0.69	N/A	88.63	N/A
11	Better decisions due to better data insight	N/A	4.41	N/A	0.61	N/A	88.13
12	Effective collaborative decision-making	4.57	N/A	0.66	N/A	91.37	N/A
	REGULATIVE FRAMEWORK						
13	Company governance	2.61	2.69	0.97	0.98	52.16	53.75
14	Collaborative alliances and partnering	3.24	3.28	0.85	0.80	64.71	65.63

Table 3: Degree of importance of skills and knowledge (currently and in five years)

Skill and knowledge dimensions	Degree of Importance Index- BIM				Degree of Importance Index- BDA			
	Current		Future		Current		Future	
	Use	Need for Training	Use	Need for Training	Use	Need for Training	Use	Need for Training
Innovation Man.	73%	76%	72%	70%	68%	78%	67%	65%
Information Man.	68%	72%	75%	72%	70%	78%	78%	70%
Team Work	66%	71%	79%	63%	63%	75%	75%	58%
Strategic Planning	58%	72%	55%	62%	46%	67%	58%	58%
Risk Man.	55%	62%	58%	56%	52%	50%	45%	62%
Legislation Man.	54%	58%	52%	52%	50%	60%	40%	70%
Communication	53%	50%	51%	57%	48%	58%	57%	47%
Leadership	53%	62%	60%	62%	52%	70%	63%	50%
Decision Making	48%	62%	64%	55%	53%	68%	67%	64%
Performance Man	48%	55%	61%	43%	43%	50%	42%	52%

This raises the question whether relatively low enhancements in certain categories of criteria for organisational competitiveness could be interpreted as a lack of impact of BIM and BDA on factors affecting productivity in those categories. For example, literature on regulative factors are acknowledged as important for both productivity

and organisational competitiveness but the measured level of enhancement for this category is significantly lower compared to the other ones. This is in line with literature which suggests that BIM creates regulative challenges in construction (Porwal and Hewage 2013). So, it could be the case that the lack of overall productivity growth is due to the lack of enhancement in certain categories of factors due to digitalisation which offsets or limits the enhancements in other categories.

When looked at different criteria within individual categories, another complex picture emerges. The highest LEI is measured for 'performance predictability' criterion by using BIM (96.47%) under 'Logistics and Operations' category. This result is supported by a study conducted by Khosrowshahi and Arayici (2012) concluding that 'predictability' nature of BIM is advantageous not only to determine project feasibility before capital is committed to a project, but also for project design, construction and operation as it lowers risks. This resonates with literature on factors affecting productivity under 'Logistics and Operations' category, such as 'supervision of operations' (see Table 1), thus implying that BIM significantly enhances some of the factors affecting productivity. In contrast, under the same category, 'research and development for innovation' scored significantly less both for BIM and BDA, 65.10% and 66.25% respectively. Considering Dubois and Gadde's (2002) argument that the lack of productivity growth in construction can be tied to lack of innovation is particularly relevant here. This is because the relatively low score for enhancement of 'research and development for innovation' then implies a lack of impact of digital technology on productivity. Overall, certain criterion under the same category scoring high and others scoring low raises the question whether it is possible to claim an overall productivity gain in individual categories of factors affecting productivity.

It is also interesting that the results show very similar behaviour between BIM and BDA when a certain criterion is considered. For example, both BIM and BDA scored relatively low for criteria under 'People' and 'Regulative Framework' categories, while scoring higher in 'Logistics and Operations' and 'Communication and Information Management' categories. This signals that although BIM and BDA could be used in a complementary way to further enhance some of the factors affecting productivity (e.g. those relating to 'Communication and Information Management'), other important factors (e.g. those relating to 'People') remain relatively less addressed even when they are used together. It is also interesting to see how BIM and BDA enhance the same criterion differently in one instance. For 'training and education processes' criterion under 'People' category, while BIM's LEI was measured as 74.90%, BDA's LEI was measured as 70.63%. This might be due to the fact that the construction industry is still in the nascent stage in terms of understanding the potential benefits of big data including the opportunities that it brings to upskill the existing workforce for efficiency improvements. However, it could also be the case that BIM provides a richer platform in comparison to BDA, thus enabling more opportunities for improved education and training leading to productivity improvements (e.g. Teizer *et al.,* 2013).

Finally, Table 3 shows that although BIM and BDA have the potential to contribute to organisational competitiveness that can be tied to productivity gains, this is dependent on the availability of certain skills and knowledge to varying extents. More specifically, Table 3 provides an overview of what is seen as critical skills and knowledge to achieve the enhancements on organisational competitiveness listed in Table 2 through the use of BIM and BDA, now, and in five years. In this sense, it can be interpreted as a picture of what skills and knowledge needs are in the industry, now, and in five years, to make improvements on a wide range of factors affecting

productivity. Importantly, Table 3 also shows the perceived training needs by practitioners, now, and in five years, thus providing a picture of where the skills and knowledge gaps are currently, and where they are likely to be in five years. One important point is that there are several areas that scored above 60% in DII for current training needs, thus pointing out to a severe skills and knowledge gap in terms of exploiting BIM and BDA for benefits of productivity. This is in line with Singh *et al.,* (2011) who suggest that uptake of BIM Level 2 is still moving at a slow pace. The interesting point is that the skills and knowledge that scored the highest degree of importance have also received some of the highest scores in terms of the need for training. This implies that the practitioners think that there is a lack of skills and knowledge in terms of what matters most to create benefits of BIM and BDA. Another important point is that while Table 2 reports a relatively low level of enhancement for innovation, Table 3 suggests that 'innovation management' is a high importance area with a high need for training thus complementing the finding in Table 2. On the other hand, surprisingly, some of the criteria that scored high level of enhancement in Table 2, such as those under 'Communication and Information Management' category, are also reported as areas that are in high need of training. It may be that certain improvements in 'communication and information management' are realised as soon as BIM and BDA are implemented but there are further potentials for further exploitation.

CONCLUSIONS

The present paper has questioned the statement that construction productivity has not been improving over the last several decades despite ongoing digitalisation. The complex relationship between productivity and digitalization is explored through a questionnaire survey on the effects of BIM and BDA on organisational competitiveness which conveniently captures factors-affecting-productivity. Generalising from the results of the survey, it can be concluded that digitalisation can be tied to productivity gains when certain skills and knowledge essential to exploit digital technologies as an organisation are in place. It is revealed that it is important to embrace digitalisation as a multi-faceted (i.e. organisational) phenomenon to create productivity improvements. This is because the results raise the concern that the lack of improvement of overall productivity might be due to the interplays between various categories of factors-affecting-productivity some of which might have been relatively less or even negatively impacted by digitalisation. Considering that both BIM and BDA mostly impact on 'communication and information management' and 'logistics and operations', it can also be concluded that digitalisation must be complemented by improvements on 'people' and 'regulative framework' related issues. There is also evidence that practitioners require training even in the domains that are most enhanced by BIM and BDA, thus suggesting that there is still room for enhancement in already highly-enhanced areas. Further research needs to conduct a larger survey considering more criteria and skills/knowledge to validate and advance the findings of this study.

REFERENCES

Abdul Kadir, M R, Lee, W P, Jaafar, M S, Sapuan, S M and Ali, A A A (2005) Factors affecting construction labour productivity for Malaysian residential projects, *Journal of Structural Surveying*, 23(**1**), 42-54.

Aziz, R F and Hafez, S M (2013) Applying lean thinking in construction and performance improvement, *Alexandria Engineering Journal*, 34 (**8**), 234-267.

Barbosa, F, Woetzel, J, Mischke, J, Maria Joao Ribeirinho, M S, Parsons, M, Bertram, N and Brown, S (2017) *Reinventing Construction Through a Productivity Revolution*. McKinsey Global Institute.

Barney, J (1991) Firm Resources and Sustained Competitive Advantage, *Journal of Management*, 17(**1**), 99-120.

Betts, M, Cher, L, Mathur, K and Ofori, G (1991) Strategies for the construction sector in the information technology era, *Construction Management and Economics*, 9(**6**), 509-28.

Betts, M and Ofori, G (1992) Strategic planning for competitive advantage in construction, *Construction Management and Economics*, 10(**6**), 511-532.

Bharadwaj, A S (2000) A resource-based perspective on information technology capability and firm performance: An empirical investigation, *MIS Quarterly*, 24(**1**), 169-96.

Böhme, T, Escribano, A, Heffernan, E E and Beazley, S (2018) Causes and mitigation for declining productivity in the Australian mid-rise residential construction sector, *Built Environment Project and Asset Management*, 8(**3**), 253-266.

Brynjolfsson, E and Hitt, L M (1998) Beyond the productivity paradox, *Communication ACM*, 41(**8**), 49-55.

Buckley, P J, Pass, C L and Prescott, K (1988) Measures of international competitiveness: A critical survey, *Journal of Marketing Management*, 4(**2**), 175-200.

Caldas, C and Gupta, A (2017) Critical factors impacting the performance of mega-projects Engineering, *Construction and Architectural Management*, 24(**6**), 920-934.

Chan, D W M and Kumaraswamy, M M (2001) Compressing construction durations: Lessons learned from Hong Kong building projects, *International Journal of Project Management*, 20(**1**), 25-35.

Çıdık, M S, Boyd, D and Thurairajah, N (2017) Ordering in disguise: Digital integration in built-environment practices, *Building Research and Information*, 45(**6**), 665-80.

Dai, J, Goodrum, P M, Maloney, W F and Srinivasan, C (2009) Latent structures of the factors affecting construction labor productivity, *Journal of Construction Engineering and Management*, 135(**5**), 397-406.

Dubois, A and Gadde, L E (2002) The construction industry as a loosely coupled system: Implications for productivity and innovation, *Construction Management and Economics*, 20(**7**), 621-31.

El-Gohary, K M and Aziz, R F (2014) Factors Influencing Construction Labor Productivity in Egypt, *Journal of Management in Engineering*, 30(**1**).

Ericsson, S, Henricsson, P and Jewell, C (2005) Understanding construction industry competitiveness: The introduction of the Hexagon framework *In: Proceedings of the 11th Joint CIB International Symposium - Advancing Facilities Management and Construction Through Innovation*, 13-16 June 2005, Helsinki, Finland.

García de Soto, B, Agustí-Juan, I, Hunhevicz, J, Joss, S, Graser, K, Habert, G and Adey, B T (2018) Productivity of digital fabrication in construction: Cost and time analysis of a robotically built wall, *Automation in Construction*, 92(**1**), 297-311.

Grilo, A and Jardim-Goncalves, R (2010) Value proposition on interoperability of BIM and collaborative working environments, *Automation in Construction*, 19(**5**), 522-530.

Harty, C, Goodier, C I, Soetanto, R, Austin, S, Dainty, A R J and Price, A D F (2007) The futures of construction: A critical review of construction future studies, *Construction Management and Economics*, 25, 477-493.

Hasan, A, Baroudi, B, Elmualim, A and Rameezdeen, R (2018) Factors affecting construction productivity: A 30-year systematic review, *Engineering, Construction and Architectural Management*, 25(**7**), 916-937.

Henricsson, J P E, Ericsson, S, Flanagan, R and Jewell, C A (2004) Rethinking competitiveness for the construction industry. *In:* Khosrowshahi, F (Ed.), *Proceedings of the 20th Annual ARCOM Conference*, 1-3 September 2004, Edinburgh, UK. Association of Researchers in Construction Management, Vol. 1, 335-42.

Jarkas, A M and Bitar, C G (2011) Factors affecting construction labor productivity in Kuwait, *Journal of Construction Engineering and Management*, 138(**7**), 811-820.

Kenley, R (2014) Productivity improvement in the construction process, *Construction Management and Economics*, 32 (**6**), 489-494.

Khosrowshahi, F and Arayici, U (2012) Roadmap for implementation of BIM in the UK construction industry, *Engineering, Construction and Architectural Management*, 19(**6**), 610-635.

Lindhard, S and Larsen, J K (2016) Identifying the key process factors affecting project performance, *Engineering, Construction and Architectural Management*, 23(**5**), 657-73.

Lu, W (2006), *A System for Assessing and Communicating Contractors' Competitiveness: (WEF) the Global Competitiveness Report*, World Economic Forum, The Hong Kong Polytechnic University.

Makulsawatudom, A and Emsley, M (2004) Critical Factors Influencing Construction Productivity in Thailand. *The Journal of KMITNB*, 14(**3**), 2547-2566.

Matusik, S F and Mickel, A E (2011) Embracing or embattled by converged mobile devices? users' experiences with a contemporary connectivity technology, *Human Relations*, 64(**8**), 1001-1030.

Naoum, S G (2016) Factors influencing labor productivity on construction sites, *International Journal of Productivity and Performance Management*, 65(**3**), 401-21.

Porter, M (1985) *Competitive Advantage: Creating and Sustaining Superior Performance*. New York: Free Press.

Porwal, A and Hewage, K N (2013) Building information modelling (BIM) partnering framework for public construction projects, *Automation in Construction*, 31,204-14.

Ross, J W (1996) Develop Long-Term Competitiveness Through IT Assets, *Sloan Management Review*, Center for Information Systems Research.

Singh, V, Gu, N and Wang, X (2011) A theoretical framework of a BIM-based multidisciplinary collaboration platform, *Automation in Construction*, 20(**2**),134-44.

Teizer, J Cheng, T and Fang, Y (2013) Location tracking and data visualization technology to advance construction ironworkers' education and training in safety and productivity, *Automation in Construction*, 35, 53-68.

Zhan, W, Pan, W, Javed, A A and Chau, K W (2018) Correlation analysis of key influencing factors to the total factor productivity of the Hong Kong construction industry *In: 21st International Symposium on Advancement of Construction Management and Real Estate*.

BLOCKCHAIN IN BUILDING LOGISTICS: EMERGING KNOWLEDGE, AND RELATED ACTORS IN SWEDEN

Dimosthenis Kifokeris and Christian Koch[1]

Division of Construction Management, Department of Architecture and Civil Engineering, Chalmers University of Technology, Sven Hultinsgatan 6, Gothenburg, 41296, Sweden

Large building projects involve complex on-site logistics regarding materials and subsystems, often encompassing hundreds of vehicles handling incoming and outcoming goods and requiring precise timing and space handling. Such a material flow is generally decoupled from the respective economic flow; however, the integration of the two could, among others, foster a holistic overview of the full construction project production, facilitate the collaboration of the supply chain stakeholders, and optimize constructability. Blockchain technologies can enable an integration of these flows by using the distributed ledger facility inherent in a decentralized blockchain network, as well as smart contracts. This paper aims at reviewing the emerging knowledge on blockchain in construction and identifying different constellations of companies and flows in digital building logistics. Theoretically, the paper draws on a sociotechnical approach, which views the development of digitalization as an intertwined social and technical process, where technology is co-shaped with practice. Building on a literature review and interviews and dialogues with actors active in building logistics within Sweden, at least three digital building logistics constellations with the potential to implement blockchain solutions are identified: (1) large contractors integrating building logistics internally, to overcome transaction challenges and maintain power over business-critical supply processes, (2) clients employing independent third-party logistics consultants acting as convenors of different interests in the building logistics setup, and (3) other third-party actors such as construction equipment suppliers, offering customised digital building logistics solutions.

Keywords: Blockchain, logistics, digital business models, information technology

INTRODUCTION

Viewed from a social interaction perspective, blockchain is a team technology - fostering collaboration to solve business challenges. In more technical terms, this is translated to blockchain being a shared and decentralized digital ledger replicated across unique nodes representing organisations or individuals; it is a peer-to-peer system for value transactions, where there is reduced need for their in-between verification, security and settlement through trusted third-party intermediaries (O'Leary 2017, Penzes 2018, Singhal *et al.,* 2018, Verhoeven *et al.,* 2018). Blockchain can act as a layer on top of the internet, as well as co-exist with other networking technologies (Singhal *et al.,* 2018). Its digital ledger databases are append-only, and every new entry is permanent, immutable, and reflected on all database replicants across the nodes (Singhal *et al.,* 2018). Each "block" in the chain

[1] christian.koch@chalmers.se

Kifokeris, D and Koch, C (2019) Blockchain in Building Logistics: Emerging Knowledge, and Related Actors in Sweden *In:* Gorse, C and Neilson, C J (Eds) *Proceedings of the 35th Annual ARCOM Conference,* 2-4 September 2019, Leeds, UK, Association of Researchers in Construction Management, 426-435.

stores a finite set of transaction- and system-related data, up to a pre-specified cumulative size; then these "blocks" are subsequently connected in a fixed order (Verhoeven *et al.,* 2018). Following the chain from the first to the latest block, the blockchain dataset does not only hold the present transactional information, but also the complete relative history (Singhal *et al.,* 2018, Verhoeven *et al.,* 2018). Such a history is shared across the nodes and can only be updated through consensus and validation, with algorithmic methods such as "proof-of-work", "proof-of-stake" and "proof-of-authority" (O'Leary 2017, Penzes 2018, Singhal *et al.,* 2018, Verhoeven *et al.,* 2018).

Blockchain was initially introduced as the underlying technology of bitcoin; however, its potential applications are actively being investigated in an emergent manner (Konstantinidis *et al.,* 2018), including its utilization as a process performance measurement tool (Kuhi *et al.,* 2018), and a facilitator of a digital ecosystem with the Internet of Things (IoT) (Woodhead *et al.,* 2018). For the building sector in general, blockchain solutions have been investigated both for the derivation of theoretical frameworks focusing on the re-engineering of entire processes, and for hands-on and focused practical development and implementation (see, for example, Barima 2017, Wang *et al.,* 2017, Penzes 2018, Li *et al.,* 2019, Nguyen *et al.,* 2019).

More particularly, in the field of on-site construction logistics and supply chain management, it has been considered that the identified issue of the disintegration of the material and economic flows (Love *et al.,* 2004, Sundquist *et al.,* 2018), can be potentially resolved with the implementation of blockchain solutions; such a potential has been noted indicatively, but not systematically, in Wang *et al.,* 2017, Dobrovnik *et al.,* 2018, Lanko *et al.,* 2018, Li *et al.,* 2019, Penzes 2018, and Rubio *et al.,* 2018. The aforementioned research efforts collectively identify that the integration of the material and the economic flows through blockchain, could aid in a holistic overview of the full construction project production, foster trust, transparency and traceability in the transactions within the flows, enhance the deliverables' quality appraisal, facilitate the collaboration of the supply chain stakeholders, and optimize constructability (which considers a holistic view on logistics, supply chain integration, and trusted stakeholder cooperation (Kifokeris and Xenidis 2017)). More importantly, such a blockchain-realized integration could formulate a new digital business model - namely, the digital transformation of organizations and business processes to create, deliver and capture value (Beck *et al.,* 2017, Konstantinidis *et al.,* 2018).

Crucial in the culmination of such a digital business model is the way the respective construction firms coordinate the relative flows (and especially the economic one). After the current short introduction on blockchain-related research in the construction context, this paper will identify different constellations of companies and economic flows in digital building logistics (particularly in Sweden), as well as the way their operation can be facilitated with the implementation of blockchain. The paper will theoretically draw on a sociotechnical approach, and methodologically will build on a literature review and dialogues with actors active in building logistics within Sweden. Following will be the discussion on the research findings and the conclusions.

A Sociomaterial Take on Blockchain

Blockchain is a digital technology with possible enactment in a number of building processes (e.g. see in Barima 2017, Penzes 2018, and Nguyen *et al.,* 2019). However, the largely non-systematic approach in most of these potential implementation efforts reveals that they are still rather visions than actual applications. Therefore,

researchers should commence an analysis of possible issues related to the embedding and interaction of blockchain within building process and practices. In the current effort, we mobilize the sociotechnical approach, where the development of digitalization is an intertwined social and technical process (Orlikowski 2016). We use one particular sociotechnical approach, namely sociomateriality, which emphasizes the way digital technologies are co-shaped with practices (Buser and Carlsson 2017, Orlikowski 2016).

According to the sociomaterial perspective, the social and the material aspects of digital technologies are inseparable (Orlikowski 2016). Particularizing this framing for blockchain in building logistics and supply chain management, it is derived that blockchain cannot be understood as separate from the processes themselves, nor their practical realization. Thus, the primary unit for research for blockchain in this context is not independent objects with well-delimited boundaries and properties, but rather phenomena materially embedded in practice (Orlikowski 2016).

One key aspect of the sociomaterial perspective is the discussion on the autonomy-control paradox (Bader and Kaiser 2017, Zuboff 2019). While the technological fundamentals of blockchain are claimed to generate trust and security, it may be more precise to understand this as a coexistence of control and autonomy. Blockchain provides overall transparency through generalized and decentralized control, but to the benefit of this transparency, the autonomy of the actors represented by the blockchain network nodes appears to be reduced (Bader and Kaiser 2017, Zuboff 2019).

It should be noted that while the sociomaterial approach can be suitable to investigate the potential of blockchain implementation within construction logistics, there is currently, within this field, little widespread understanding of the underlying technology, making the respectively dedicated and/or knowledgeable researchers relatively rare. Due to this limitation, the conceptualization and realization of certain frameworks and solutions may involve blockchain experts not necessarily familiar to the particularities of construction supply chains and logistics, thus potentially resulting in a partial de-contextualization of the respective research efforts.

Constellations of Digital Building Logistics in Sweden

Currently, Sweden is experiencing heated construction activity associated with complex coordinating processes, leading to a potential series of logistics-related issues (e.g. delayed deliveries, complicated supply chain coordination, and low productivity) (Dubois *et al.,* 2017). To ameliorate such issues and facilitate all associated logistics services, certain constellations of digital building logistics and their potential for integration with blockchain, can be highlighted. Drawing on the understandings of the aforementioned sociomaterial framework and its set of perspectives, the basic literature results of the introductory section, and interviews and dialogues with actors active in building logistics within the Swedish construction sector, at least three such constellations are identified - along with their primary proponents, their realization of the economic flow, and ultimately their take on a relative digital business model:

11. Large contractors integrating building logistics competences internally, to overcome transaction challenges and maintain power over business-critical processes of the material supply and its reflection on the economic flow.
12. Clients employing small independent logistics consultants, whose digital business model can then be enlarged with blockchain, and who can appear as independent conveyors of different interests in the building logistics setup.

13. Third-party players such as construction equipment suppliers, or industrialised housing suppliers, offering digital building logistics solutions.

The identification of these three business models was derived by targeted literature findings and the input of practitioners working within organizations that constitute typical examples of each of the three constellations. Such input consisted of statements, descriptions and procedural documents, and was solicited through unstructured interviews; finally, it was compared with the literature review results, and was critically scrutinized through the sociomaterial perspective. As a result, an analysis on each of the constellations is respectively featured in the following three subsections. It should be noted that these constellations are not the only ones that may act within the Swedish construction sector and building logistics; however, they appear to be the most dominant. Moreover, project governance, and institutional and cultural context, should also be considered as potentially impactful factors on the respective business models. However, due to space limitations, these factors are consciously not considered in the present paper and are left for further research work; the sociomaterial approach is utilized only in the ways previously delineated.

The Internalized Building Logistics Organization

It is often seen at large construction sites in Sweden to rely on the interaction of a range of actors, mainly contractors, purchasers, subcontractors, retailers and other material suppliers, and transporters (Sundquist *et al.,* 2018). Especially in heavily urbanized areas, a network of material and equipment storage places, local offices, retailer facilities and other infrastructure, is permanently in place in the vicinity, to support a newly specified large building site. For example, this was the initial state of the site for the project Urban Escape, namely a currently built district in Stockholm (Juhlin 2018). The way this initial state was changed by the operation of third-party actors offering digital building logistics services, is described in the third subsection.

In such an environment, most operating contractors (e.g. Veidekke Sweden) have chosen to integrate the corresponding building logistics competences and services internally. That way, they attempt to overcome transaction challenges (which would have been prevalent if such services were delegated elsewhere) and maintain power over business-critical processes of the material supply and its reflection on the economic flow and the workplace costs - namely, all costs incurred at the construction site but not directly included in the production of buildings, such as work management, machines, workstations, sanitation, construction lifts (Juhlin 2018). This approach can be characterized as relying on existing supply nodes and routes, since order release, incoming transport, on-site material placement, and even subsequent payments, are largely organised by many actors in parallel each relying on their own supply set up, with little coordination before the arrival on site. This leads to occasional congestion and bottlenecks in incoming flow, e.g. when a single road provides access to a site, or a single main gate has to be passed by all incoming transport.

The economic flow passes certain human-information system nodes, such as the client's accountant utilizing one accounting system, and the main contractor's accountant utilizing another. The corresponding ledgers are organised according to each actor's business practice, and they are rarely commonly structured along general standards. Observing the corporate-level function even within the contractor firms

themselves, there can be a discrepancy in the way the economic flow is realized and disseminated among the different business units.

In such a situation, the transition to a digital business model utilizing blockchain for building logistics with integrated material and economic flows, would mean that a generalized, decentralized and common digital ledger would be used by all the related actors, and thus the discrepancy in the utilization of different accounting systems would be significantly mitigated. While there can be different levels of blockchain integration within the economic flow-related aspects of the existent business model, the normalization of the whole process brought about by the append-only aspect of the block creation, along with the immutability of the chain itself, would give a certain impetus to at least adopt a basic level of decentralization in the relative processes.

The Atypical Use of Independent Building Logistics Consultants

To ameliorate logistics issues and facilitate all associated logistics services, an emerging business practice is the employment of independent third-party logistics consultant firms (such as LogTrade, Myloc, Prolog Bygglogistic, Servistik, Svenskt Byggdialog, Svenskt Bygglogistic, and FM Management), which coordinate and handle complex, recurrent and conflicting flows consisting of deliveries of materials, arrival of incoming goods, payments for deliveries and services, and other sub-systems. These firms are often small organizations; they embody a business model for improved construction logistics, strengthening the coordination across the supply chain by connecting the client, the material and equipment transport companies, the contractors, and the subcontractors (Gustavsson 2018).

However, there are several different approaches and levels of digitalization in the way these firms coordinate logistics. In some cases, "traditional" and/or established methods and tools are utilized, while in others there is support by advanced IT infrastructure (either in-house or outsourced to specialized IT consultants), such as planning and tracking software systems. These approaches do not have to be mutually exclusive; both can and sometimes are being used to some extent, but in a generally fragmented and disintegrated manner. However, all approaches involve interactive on-site collaboration with key suppliers and/or other stakeholders within the construction supply chain; this is important to the value proposition of the business model of such firms. At present, the parallel economic flow is often organised similarly to the model sketched in the previous subsection.

The digitalization of such a business model (or enhancement of an already digital one) through blockchain, can optimize the efficiency of these firms, and lower their costs (McKinsey Global Institute 2017). Blockchain properties align with viewing such a digital business model not as a single-company effort, but instead an inter-organizational one (Vendrell-Herrero *et al.,* 2018) - as is the case when partnering with logistics consultants. In such a context, this digital business model could involve partnerships between incumbent product-oriented firms and digitally capable newcomers, to foster the agility of supply chains (Vendrell-Herrero *et al.,* 2018).

Apart from the collaborative aspect mentioned above, digital business models for construction logistics can benefit from a simultaneously integrated and agile approach (Thunberg and Fredriksson 2018). Through such an approach, on-site space usage for provisional storage reflecting ongoing changes of spatial options and limitations could substitute the more static “Area Disposition Plan” (APD). While APD is usually referred to as dynamic, there is rarely an actual and continuous integration between

the logistics planning and flow control system, and the material registration, placement and installation. A blockchain solution integrating the economic flow and material flows, could facilitate such agility (O'Leary 2017).

Logistics consultants can also lead to the realization of the integrated and agile aspects mentioned above. However, delivery failure, unprecise data retrieval, time delays, intra-systemic inefficient flows and data transfers, and the disintegration of the on-site physical placement with any implemented digital solutions, are still hindering the consultants' efforts. Even more crucially, the economic flow brought about by these consultants is still ambiguous. Not only their coordination of the invoices to be paid after any successful deliveries and/or finished works has not fully eliminated issues of delay and complacency, but the consultants themselves are also burdened with justifying the value-for-money for their services - the disintegration of the flows is widened in the decoupling of the payments for the deliveries and transportations, and for the logistics services.

Thus, it can be derived that the current state of affairs of the logistics consultants both:

- Presents a fertile ground for a digital business model for construction logistics using blockchain to integrate the material and economic flows;
- Needs such a digital business model. Even among more digitally advanced logistics consultants, issues like on-site disintegration and of value-for-money justification, have still to be tackled.

It should be noted that the employment of these independent logistics consultants is not common. While there are clients that actually ask for them (e.g. the public clients of the whole district development in the area of Järfälla, Stockholm), in most cases the building projects are either contracted to actors already internalizing logistics services (see previous subsection), or there is a utilization of the limited services of third-party players (see the following subsection).

Third-Party Actors Offering Dedicated Digital Building Logistics Services

The placing of the tasks, as well as the organisation and management of building logistics can be set up in a larger number of ways, often with third-party actors offering unique and/or out-of-the-box solutions and digital services. Among these, a reported case is an equipment supplier, Ramirent (Juhlin 2018).

Ramirent normally leases machines and other equipment to construction sites. But in the case of the large site for the aforementioned multibuilding project Urban Escape, they offered a comprehensive concept for building logistics (Juhlin 2018). The client and developer needed a logistics solution for a congested site with many operating stakeholders and main contractors, and a concept of a temporary factory. Ramirent changed their ordinary business model and engaged in providing the entire logistics concept, including site access technologies. The site was split in six major zones, given to three major contractors Skanska, NCC and Zengun. These six zones featured different access points and transportation routes (Figure 1).

The temporary factory was a hybrid framework drawing from the contractors' way of realizing the building production, along with new suggestions and concepts brought about by Ramirent (Juhlin 2018). The function of this temporary factory was translated into a new way of planning, organizing, visualizing, performing, and invoicing temporary parts of the building that do not directly concern the construction of permanent buildings, such as taking up the responsibility for common areas and functions (e.g. reception, changing and dining rooms, cleaning), visualization of

processes in time and space with the help of Building Information Models (BIM), development of logistics plans, construction of temporary facilities (e.g. buildings, elevators, electricity infrastructure, scaffolding), waste management activities, rental of machinery, development of new digital support tools, growth of new competencies, and provision of enclosures and guards. Ramirent outsourced the individual tasks to external partners, including a BIM-competent company. This enabled the active use of visualisation in the temporary factory design, and the integration of design and production planning in 4D BIM. The temporary factory also involves a site-placed machine rental centre, which all participating contractors are supposed to use.

Figure 1: Picture of Urban Escape. Lower left and right areas - Skanska, Upper left and upper right areas, garage and Gallerian - Zengun, Upper centre area - NCC (adapted from Juhlin 2018).

Thus, Ramirent has created a market for itself and can leverage a better capital investment, as a type of a blue ocean strategy (Juhlin 2018), despite expanding to an area of lower profitability. This process can furtherly by strengthened by introducing blockchain to the respective digital business model, by streamlining the decentralized economic flow of on-site planning (already "flattened" to ease on-site congestion), along with the multiple material flows connected to the differently designated site areas and access points.

DISCUSSION

When reviewing the emerging knowledge on blockchain in construction, as well as the characteristic types of building logistics set-up in Sweden, it can be clearly understood that the processes in and around building logistics represent a possible field of blockchain implementation. The different set-ups represent different business models, and thus different modes of collaboration between the participating parties in a blockchain network. Rather than viewing these different set-ups as technical choices among rationally discernible models, which is recurrent in operational management and business economics approaches, we interpret them here as different sociotechnical solutions involving characteristic distributions of power. Where the first often seen set up would imply a "business as usual" power balance, the second introduces an apparently neutral actor, that can facilitate the logistics flow. These small independent consultants usually enter into the scene based the clients' request, and they are given a pivotal role according to the clients' power and prerogative. In the third case, the strategic movement of a machine rental company is currently stirring up uneasy reactions not only from other collaborating parties on site, but also from its own shareholders, who are worried about reduced revenue due to moving into the less attractive business area of building logistics (Juhlin 2018). So, in all of these

cases, it is evident that the corresponding operational frameworks have to do not only with knowledge exchange (Gustavsson 2018), but also constitute a type of a political game. Hence, the adoption of blockchain solutions for building logistics with integrated material and economic flows within new digital business models for the actors of each of these constellations, should also consider this dimension.

A crucial issue is security in blockchain implementation and the related need for mutual trust (Woodhead *et al.,* 2018). In terms of security, it is recurrent that large urban building sites suffer from theft and shrinkage in material supplies. As such, internal trust among participants in a blockchain network, in which there is inherently no centralized control, should be cultivated - however, it is difficult to support such an endeavour. It may be necessary to set up a permissioned system and follow a series of procedures to not only protect the blockchain network from external threat, but also internal instabilities. In addition, the matter of integration involves technical interoperability issues, as well as changes in the work practices and organisation of the participating companies. The introduction of a blockchain solution to integrated building logistics would probably place it, at first, on top of an information infrastructure consisting of a series of different accounting, project planning, quality control, access control, and site planning systems; then, the adoption of common standards, not only for building components, but also for the structuring of ledgers, will enter the agenda.

A series of further issues that cannot be covered due to space limitations, can further illustrate the sociotechnical character of the phenomena under research. In a wider perspective, blockchain is only one digitalisation technology; integration and cross-fertilization of the IoT, machine learning, digital twin, automated vehicles, augmented reality, and other digitalization technologies, will emerge as possibilities.

CONCLUSIONS

This paper aimed at reviewing, in a targeted manner, the emerging knowledge on blockchain technology within construction, and identifying some different set-ups of related actors and flows in digital building logistics, to facilitate the conceptualisation and contextualization of using blockchain solutions. Scrutinizing these findings through the sociomaterial perspective (namely, that the social and the material parts of digital technologies are inseparable), we found three main sociotechnical constellations that might be able to adopt blockchain solutions: The business as usual contractors internalizing logistics services, the independent building logistics consultants, and the unique third-party actors, as in the case of a construction machine rental company taking up logistics in a large building site. Each is characterized by its own challenges and power structures. In all cases, implementing blockchain entails a long series of negotiations, and requires the tackling of issues, such as cyber security and integration with other information systems.

REFERENCES

Andreini, D and Bettinelli, C (2017) *Business Model Innovation: from Systematic Literature Review to Future Research Directions*. Cham: Springer Nature.

Bader V and Kaiser S (2017) Autonomy and control? How heterogeneous sociomaterial assemblages explain paradoxical rationalities in the digital workplace, *Management Revue,* 28(**3**), 338-358.

Barima, O (2017) Leveraging the blockchain technology to improve construction value delivery: The opportunities, benefits and challenges, *In: Construction Projects: Improvement Strategies, Quality Management and Potential Challenges*. New York: Nova Publishers, 93-112.

Beck, R, Avital, M, Rossi, M and Thatcher, J B (2017) Blockchain technology in business and information systems research, *Business and Information Systems Engineering*, 59(**6**), 381-384.

Buser, M and Carlsson, V (2017) What you see is not what you get: Single-family house renovation and energy retrofit seen through the lens of sociomateriality, *Construction Management and Economics,* 35(**5**), 276-287.

Dobrovnik, M, Herold, D M, Fürst, E and Kummer, S (2018) Blockchain for and in logistics: What to adopt and where to start, *Logistic*s, 2(**18**), 1-14.

Dubois, A, Hulthén, K and Sundquist, V (2017) Organising logistics and transport activities in construction, *International Journal of Logistics Management*, 30(**2**), 620-640.

Gustavsson, T K (2018) Liminal roles in construction project practice: Exploring change through the roles of partnering manager, building logistic specialist and BIM coordinator, *Construction Management and Economics*, 36(**11**), 599-610.

Juhlin, M (2018) *Faktisk Innovation I Bygg- Och Anläggningsbranschen*. Stockholm: Policy Impact AB.

Kifokeris, D and Xenidis, Y (2017) Constructability: Outline of past, present and future research, *Journal of Construction Engineering and Management*, 143(**8**), 04017035.

Konstantinidis, I, Siaminos, G, Timplalexis, C, Zervas, P, Peristeras, V and Decker, S (2018) Blockchain for business applications: A systematic literature review *In:* W Abramowitz and A Paschke (Eds.) (2018) *Business Information Systems - 21st International Conference BIS 2018*, Berlin: Springer, 384-399.

Kuhi, K, Kaare, K and Koppel, O (2018) Ensuring performance measurement integrity in logistics using blockchain, *In: 2018 IEEE International Conference on Service Operations and Logistics and Informatics (SOLI),* New York: Curran Associates, 256-261.

Lanko, A, Vatin, N and Kaklauskas, A (2018) Application of RFID combined with blockchain technology in logistics of construction materials, *MATEC Web of Conferences*, **170**, 03032-1-03032-6.

Li, J, Greenwood, D J and Kassem, M (2019) Blockchain in the construction sector: A socio-technical systems framework for the construction industry, *In:* Mutis, I and Hartmann, T (Eds.) (2019) *Advances in Informatics and Computing in Civil and Construction Engineering*. Cham, Switzerland: Springer Nature, 51-57.

Love, P E D, Irani, Z and Cheng, E D J (2004) A seamless supply chain model for construction, *Supply Chain Management: An International Journal*, 9(**1**), 43-56.

McKinsey Global Institute (2017) A future that works: Automation, employment and productivity, New York: McKinsey Global Institute.

Nguyen, B, Buscher, V, Cavendish, W, Gerber, D, Leung, S, Krzyzaniak, A, Robinson, R, Burgess, J, Proctor, M, O'Grady, K and Flapper, T (2019) *Blockchain and the Built Environment*. London: Arup.

O'Leary, D E (2017) Configuring blockchain architectures for transaction information in blockchain consortiums: The case of accounting and supply chain systems, Intelligent Systems in Accounting, *Finance and Management*, 24(**4**), 138-147.

Orlikowski, W J (2016) Digital work: A research agenda, *In:* Czarniawska, B (Ed.) (2016) *A Research Agenda for Management and Organization Studies.* Northampton: Edward Elgar Publishing, 88-96.

Penzes, B (2018) *Blockchain Technology in the Construction Industry: Digital Transformation for High Productivity*, London: Institution of Civil Engineers (ICE) Publications.

Rubio, M A, Tarazona, G M and Contreras, L (2018) Big data and blockchain basis for operating a new archetype of supply chain, *In:* Tan, Y, Shi, Y and Tang, Q (Eds.) (2018) *DMBD 2018, LNCS 10943.* Cham: Springer International Publishing AG, 659-669.

Singhal, D, Dhameja, G and Panda, P S (2018) *Beginning Blockchain: A Beginner's Guide to Building Blockchain Solutions*, New York: Apress.

Sundquist, V, Gadde, L E and Hulthén, K (2018) Reorganizing construction logistics for improved performance, *Construction Management and Economics*, 36(**1**), 49-65.

Thunberg, M and Fredriksson, A (2018) Bringing planning back into the picture - How can supply chain planning aid in dealing with supply chain-related problems in construction? *Construction Management and Economics*, 36(**8**), 425-442.

Vendrell-Herrero, F, Parry, G, Bustinza, O and Gomes, E (2018) Digital business models: Taxonomy and future research avenues, *Strategic Change*, 27(**2**), 87-90.

Verhoeven, P, Sinn, F and Herden, T T (2018) Examples from blockchain implementations in logistics and supply chain management: Exploring the mindful use of a new technology, *Logistics*, 2(**3**), 20.

Wang, J, Wu, P, Wang, X and Shou, W (2017) The outlook of blockchain technology for construction engineering management, *Frontiers of Engineering Management*, 4(**1**), 67-75.

Woodhead, R, Stephenson, P and Morrey, D (2018) Digital construction: From point solutions to IoT ecosystem, *Automation in Construction*, 93, 35-46.

Zuboff, S (2019) *The Age of Surveillance Capitalism: The Fight for a Human Future at the New Frontier of Power*. London: PublicAffairs.

ENVIRONMENTAL

SYSTEMS THINKING AND MODELLING FOR BUILDINGS' SUSTAINABLE SITE SELECTION

Walaa S E Ismaeel[1]

The British University in Egypt, Faculty of Engineering, Architectural Engineering Department, El Sherouk City, Egypt

Sustainable site selection is considered the first challenging step in the decision-making process for green buildings. It has a progressive effect on the rest of the sustainable categories. Nevertheless, these intrinsic effects are unexploited. Accordingly, this study uses systems thinking and modelling approaches to represent and simulate the feedback loops for proper site selection under 'Leadership in Energy and Environmental Design' (LEED) system. The results indicate that 42% of available points are directly related to site potentials, while 21% are indirectly related- which in sum qualifies the project to the Gold certification level. It also shows dominant and latent feedback loops with other sustainable categories; achieving less energy consumption and water use, promoting the use of green materials and resources as well as providing better indoor environmental quality. Furthermore, it indicates that LEED energy and atmosphere is the most affected category by decisions related to site selection. The presented model sets an objective base for site selection and provides valuable research output for academic and industry outreach.

Keywords: LEED; sustainable site selection; systems thinking, modelling

INTRODUCTION

Selecting building site location is a crucial decision that should consider the whole complex system of green buildings through feedback loops. These would, in turn, carry intrinsic implications on building's energy performance, water use, available green materials and resources as well as providing indoor comfort and air quality. This, in turn, pinpoints the urgent need to develop practitioners' awareness in this regard using advanced knowledge and application of systems thinking.

Leadership in Energy and Environmental Design (LEED) is an internationally and widely applied and accepted building rating system which includes guidance for sustainable site selection within two categories; 'Location and transportation' (LT) and 'Sustainable Sites' (SS). These tackle context and site related aspects, respectively. It is noteworthy that the point scoring mechanism of LEED allows performing quantitative analysis. However, the intrinsic synergies between site selection aspects and other LEED sustainable categories are unexploited which represents a main gap in the existing literature. Accordingly, the author argues that applying dynamic system thinking shall no doubly expand the mental model of decision makers therein.

[1] Walaa.Salah@bue.edu.eg

Ismaeel, W S E (2019) Systems Thinking and Modelling for Buildings' Sustainable Site Selection *In:* Gorse, C and Neilson, C J (Eds) *Proceedings of the 35th Annual ARCOM Conference,* 2-4 September 2019, Leeds, UK, Association of Researchers in Construction Management, 437-444.

Eventually, this shall improve the comprehension of green buildings' performance and discloses intrinsic interrelations of synergies and trade-offs of sustainable aspects; noting that it is practically impossible to act on one factor without affecting the other. This requires a holistic view for their interrelations to maintain their consonance with long term benefit of the entire system instead of individual practices or building elements (Folke *et al.,* 2010; van Kerkhoff, 2014). On one hand, the high leverage points of proper site selection are identified to produce sustainable benefit and catalyse sustained change along the building's life cycle (Gou and Xie, 2017). On the other hand, improper site selection may result in downsizing building performance. These may arise due to an incomplete understanding of feedback loops operating in the system in addition to any side effects which signify flaws and short-sight comprehension of the system's structure, behaviour or feedback loops (Sterman, 2002; Thompson and Bank, 2010). Hence, the site selection process has to be investigated within the various arrays of other sustainable categories to show its influential structure with other sustainable aspects. Accordingly, the LEED system's sustainable guidelines and score weighting mechanism have been used to define parameters which may directly or indirectly be affected as a result of site selection. It is divided into main categories and a number of credits in each. Very few studies have discussed means of assessing the sustainability of sites and fewer have discussed its impact on other sustainable aspects. Building on this conceptual model shall add to the existing body of knowledge for scholars and practitioners to provoke new ways of thinking, acting and responding to building site selection.

Systemic Approach

Recent studies have applied the science of systems thinking as a novel method for life cycle behaviour simulation of sustainable buildings (Marzouk and El-Hawary, 2017). This has highlighted its role for greening residential building stock (Cihat, Egilmez and Tatari, 2014) and as a tool for decision-making in aspects related to building design and operation (Thompson and Bank, 2010). It has also been used to investigate the aggregation of archetype buildings in national building-stock in different European countries and its effect on their energy consumption and carbon emissions (Kalagasidis and Johnsson, 2014; Eker *et al.,* 2018). It is also noted that the application of systems thinking approach allows the integration with Building Information Modelling (Bank *et al.,* 2010; Zou, Kiviniemi and Jones, 2017) and other advanced software programs for modelling problems associated with the building industry. Hence, the Geographic Information System was applied to model building stock data (Bu *et al.,* 2017) and develop an urban level bottom/up model (Österbring *et al.,* 2016).

A number of previous studies have presented modelling approaches and calculation methods for energy efficiency in building-stock (Kavgic *et al.,* 2010; Frayssinet *et al.,* 2018). These have considered factors of building energy use and consumption, emissions as well as cost (Mata, Kalagasidis and Johnsson, 2013). It has also been applied to investigate scenarios of reducing the carbon footprint on the city level (Ercan, Cihat and Tatari, 2016) and to comply with national strategic policies of European countries (Holck *et al.,* 2016). Nevertheless, the effect of location and time change has been rarely investigated in this regard (Fonseca and Schlueter, 2015). Thus, the use of dynamic system thinking is considered an open field of study particularly for solving problems with dynamic complex nature and varying interacting parameters such as green buildings.

RESEARCH METHOD

The research method is divided into three steps; applying systems thinking for sustainable site selection problem, developing the model and finally testing it.

Applying Systems Thinking for Sustainable Site Selection

LEED project checklist and score weighting calculator are used to determine site-dependent credits. This process is performed by the author and double checked by ten qualified independent academics specialized in urban design and planning to ensure reliability and avoid the bias of the outcome results. The intrinsic interrelationships are shown in Fig. 1

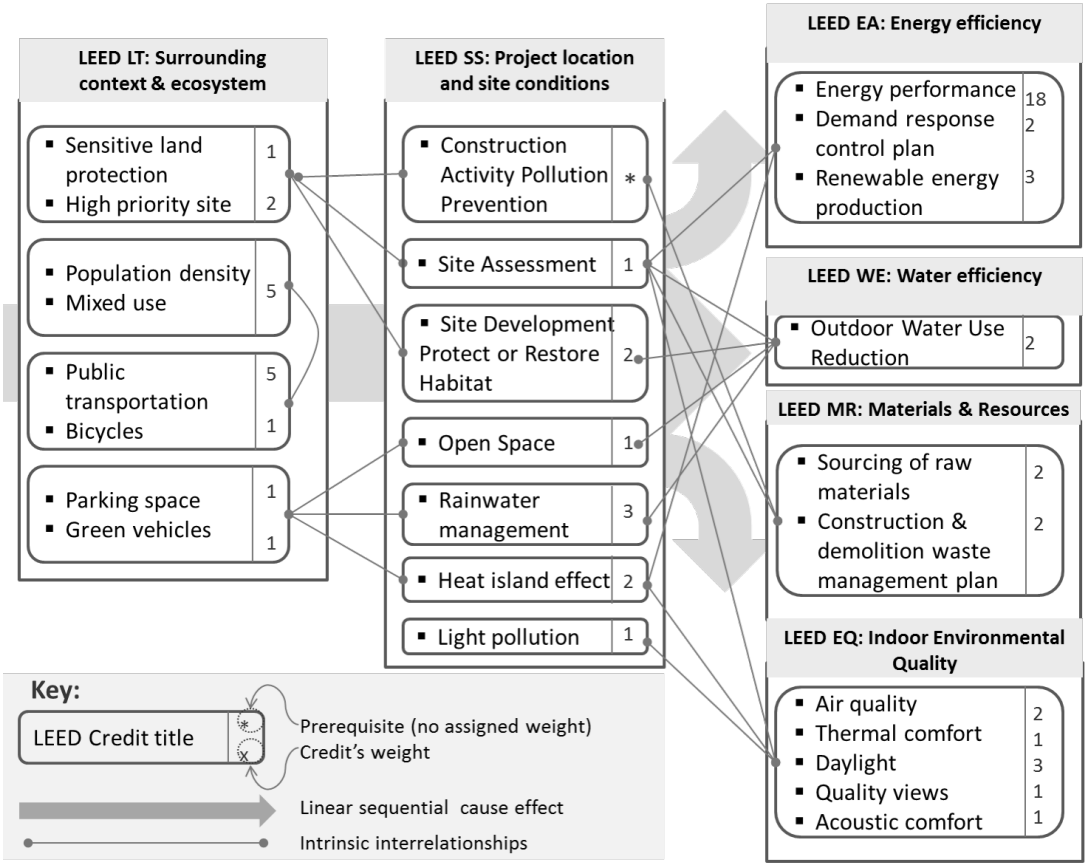


Figure 1: Determining Site-dependent LEED credits

Then, the dependency coefficient of credits and categories in relation to site selection is calculated as a percentage of total available points. Example, Credit: 'Outdoor Water Use Reduction' is assigned 2 LEED points, and credit's content explains the direct connection with site conditions, hence, the study defines it as site dependent-credit, and calculates the dependency coefficient of LEED WE category as total weight of site-dependent credits/ assigned score weight of the category according to LEED checklist, hence, WE is found to be 2/11=18.18%, and similarly for the rest of LEED credits and categories. Hence, LEED main categories; LT, SS, Water Efficiency (WE), Energy and Atmosphere (EA), Materials and Resources (MR) as well as Indoor Environmental Quality (IEQ) were found to have dependency coefficient factors of; 100%, 100%, 18%, 70%, 31% and 50%, respectively. It is noted that LEED for 'Neighbourhood Development Location' credit is excluded to avoid double counting. Similarly, the bonus points assigned for LEED Innovation in

Design and Regional Priority categories have also been excluded because they are awarded according to the project's individual conditions.

Modeling Description

Putting LEED categories in a larger system model establishes a form of combinatorial complexity which requires a detailed investigation of their internal structural components and subcomponents. Thus, using the previous quantitative analysis, a simulation model has been developed using VENSIM PLE software program. This shows the aim of the model, limits of the model boundary, subsystems and feedback relationships.

The target of the model is to investigate scenarios of point accumulation of site-dependent credits under LEED categories with regards to site selection. The model boundary includes main LEED categories (acting as systems' agents e.g. LT) and the subsystems include site-dependent credits e.g. 'High priority site'. Point accumulation has been defined as 'Stocks' where they act as inventories of gaining points over time according to compliance with different LEED credits therein. The rate of point accumulation over time is represented for each category e.g. LT*. Decisions, in turn, alter the rate of flow (increase/ decrease in the stock) of point accumulation in each of the defined categories, altering the stocks and closing the feedback loops in the system.

Furthermore, the dynamic system of complex criteria has been represented in a number of feedback loops-denoted by → upon which their integration determines the level of complexity of interrelated sustainable parameters with those related to site selection over time. These created path dependences (e.g. between High priority site and LT*) signpost positive (synergies) or negative (trade-offs) feedback loops. They also highlight dominant and latent loops affecting the structure and behaviour of the system. This considers the time delay amid deciding on the project's site and its effect on the state of the system. It also indicates irreversible consequences of selecting project's site location which may lead to high leverage points or otherwise the system's resistance throughout the project's development. Hence, in this example, it is a dominant feedback loop which may be positive if the project site has potentials to obtain points under LEED LT category that may lead to gaining points under other LEED credits. It is also considered an exogenous variable because the link to the site potential is clearly indicated.

Testing

Hypothetically, the project development timeline has been represented as points (1-6) where every point represents 2 months of project development on one of LEED theme categories. After developing the model, it has been double-checked for dimensional consistency and model sensitivity in extreme conditions. This is carried out to discover flaws and enable an enhanced comprehension of all related parameters to site selection. Accordingly, two case scenarios have been simulated; LT=0 (01) and SS=0 (02) to test the extreme case scenario of losing points under the LT and SS categories, respectively. The ideal case (reference mode characterized by linear flows of point accumulation and no time delays) represents the state of point accumulation (y-axis) with respect to the project development phases (x-axis). This shows that ideally, the project status allows an initial launching of 16 points owing to obtaining points under the LT category, then, it develops through aspects related to SS, WE, EA, MR and EQ, respectively. For simplification, a sequential process of earning points is

assumed; nevertheless, the real complexity arises from the concurrency and interaction of parameters responsible for obtaining points under each of these categories in time. Then, a number of case scenarios have been compared to the reference mode to showcase its effect on other LEED categories.

RESULTS AND DISCUSSION

This research has used the science of systems thinking to study the complexity of sustainable site selection using LEED assessment criteria. It was found that this complexity does not only arise from the two involved LEED categories (LT and SS) in isolation but their interaction with other sustainable categories (WE, EA, MR and IEQ) over time and space as shown in Fig 2.

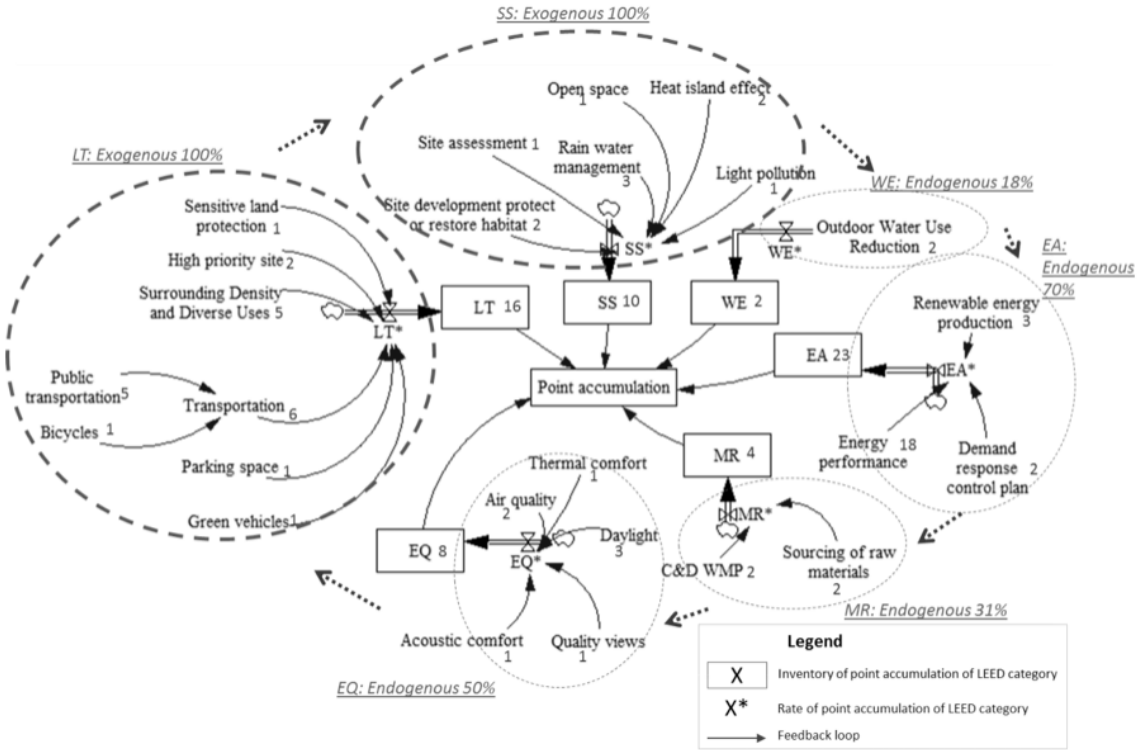


Figure 2: Mapping system structure using the stock and flow model of Vensim PLE software program

Studying these intrinsic relations reveals that proper site selection may earn the project 63% of total available points which qualifies it to the Gold certification level (the second highest level awarded) as shown in Fig. 3. Both LEED LT and SS categories are considered exogenous variables to site selection, while other sustainable categories can be considered endogenous factors with varying degrees; the EA category is the most dominant feedback loop in this regard. These create positive dependency paths between them which directly affect the building performance. Comparing the two case scenarios of extreme conditions to the reference case is shown in Fig. 4. It shows that the rate of point accumulation in the case of LT=0 affects the overall initial project's score weighting but it does not possess the same influence compared to the case when SS=0. This indicates that the project's site-related aspects have direct relationship to other sustainable categories more than its contextual location.

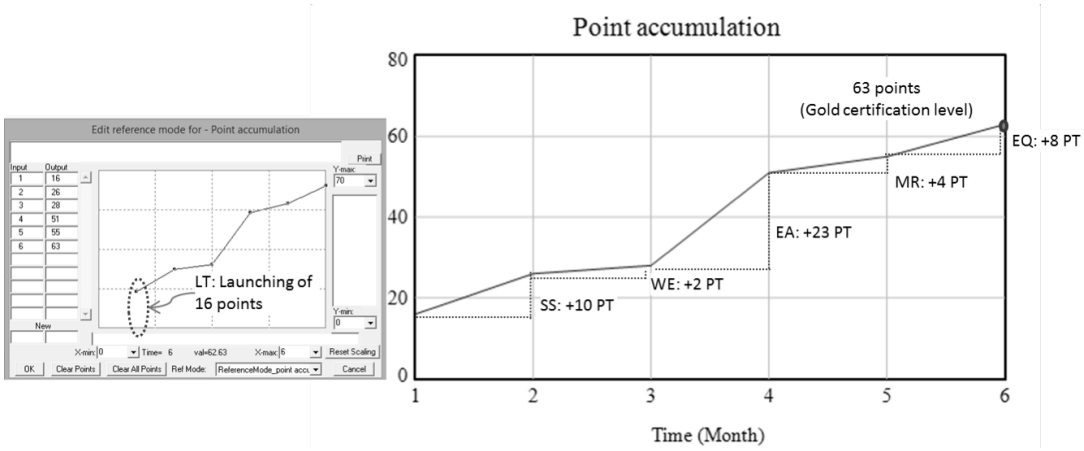


Figure 3: The reference mode for the rate of point accumulation of different LEED categories over time (assuming 12 months project time completion from start to finish), developed from Vensim PLE software program

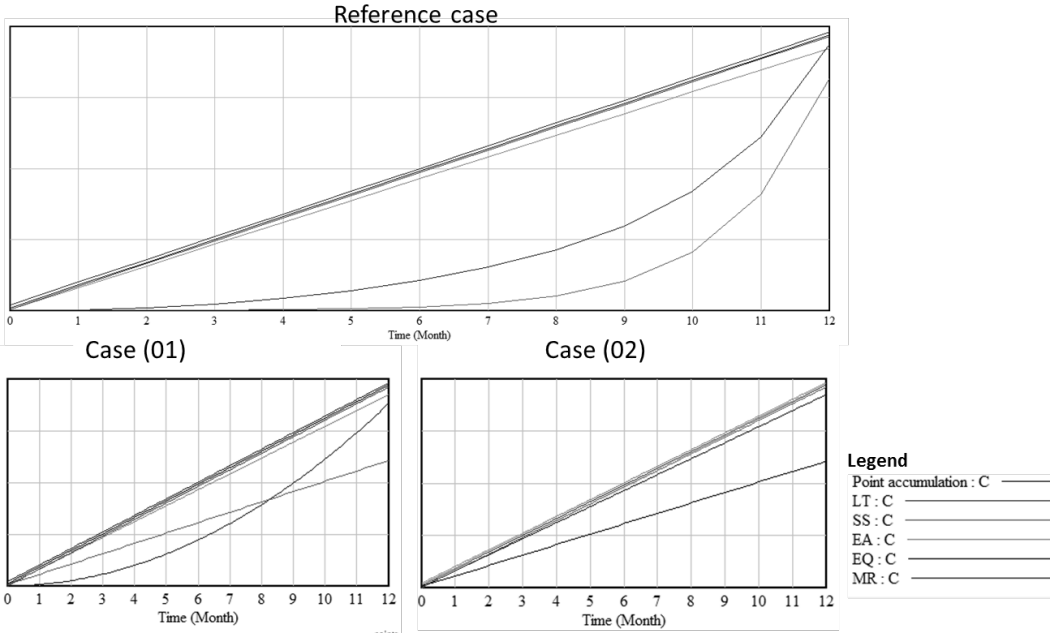


Figure 4: Reference case, two case scenarios, LT=0 (Case 01) and SS=0 (Case 02), developed from Vensim PLE software program

CONCLUSION

This study provides a useful heuristic for conceptualizing buildings as dynamic systems pointing out the effect of site selection. The model adopted in this study presents a pilot attempt to apply systems thinking and modelling approaches to formulate a basis for understanding the challenges associated with a project's site selection. This should be integrated into early project phases to establish an iterative process of joint inquiry that would, in turn, develop a new understanding of the complexity of this problem.

The presented model shows a significant relationship between the structure and behaviour of any sustainable building in terms of the effect of proper site selection on other sustainable parameters. This also reveals dominant and latent feedback loops during project development which would, in turn, affect the patterns of point-gaining of LEED categories and alter the system's response therein. It has been more

significant for LT and SS categories (exogenous variables) which have direct relationships to site selection. Furthermore, other indirect relationships have also been revealed; with EA, IEQ, MR then WE categories (endogenous variables).

Finally, it is interesting to note that there is no wrong or right in system modelling, the model is usually assessed according to how appropriate it has addressed the aims and objectives of the study. For this investigative level of study, it is believed that it has reached an appropriate level of completeness; nevertheless, for advanced levels of research, the combinatorial complexity of feedback loops for site-dependent credits may be taken to further detailed subsystems' levels. It would also allow researchers to define internal high leverage points and consider the distant behaviour in time and space between cause and effect which may occur at varying interacting time scales.

REFERENCES

Bank, L C, Mccarthy, M, Thompson, B P and Menassa, C C *(*2010) Integrating BIM with system dynamics as a decision-making framework for sustainable building design and operation, *In*: *First International Conference on Sustainable Urbanization (ICSU)*, 15th - 17th December, Hong Kong.

Bu, R, Froemelt, A, Heeren, N, Raubal, M and Hellweg, S *(*2017) Big data GIS analysis for novel approaches in building stock modelling, *Applied Energy*, 208, 277-290.

Cihat, N, Egilmez, G and Tatari, O (2014) Towards greening the US residential building stock: A system dynamics approach, *Building and Environment*, 78, 68-80.

Eker, S, Zimmermann, N, Carnohan, S and Davies, M *(*2018) Participatory system dynamics modelling for housing, energy and wellbeing interactions, *Building Research and Information*, 46(**7**), 738-754.

Ercan, T, Cihat, N and Tatari, O (2016) Investigating carbon footprint reduction potential of public transportation in United States: A system dynamics approach, *Journal of Cleaner Production*, 133, 1260-1276.

Folke, C, S R, Carpenter, B, Walker, M, Scheffer, T, Chapin and Rockström, J (2010) Resilience thinking: integrating resilience, adaptability and transformability. *Ecology and Society*, **15**(4), 20.

Fonseca, J A and Schlueter, A (2015) Integrated model for characterization of spatiotemporal building energy consumption patterns in neighbourhoods and city districts, *Applied Energy*, 142, 247-265.

Frayssinet, L, Merlier, L, Kuznik, F, Hubert, J-L, Milliez, M and Roux, J-J (2018) Modeling the heating and cooling energy demand of urban buildings at city scale, *Renewable and Sustainable Energy Reviews*, 81, 2318-2327.

Gou, Z and Xie, X (2017) Evolving green building: triple bottom line or regenerative design? *Journal of Cleaner Production*, 153, 600-607.

Holck Sandberg, N, Sartori, I Heidrich, O, Dawson, R, Dascalaki, E, Dimitriou, S, Vimm-r, T, Filippidou, F, Stegnar, G, Zavrl, M S and Brattebø, H (2016) Dynamic building stock modelling: Application to 11 European countries to support the energy efficiency and retrofit ambitions of the EU, *Energy and Buildings*, 132, 26-38.

Kalagasidis, A S and Johnsson, F (2014) Building-stock aggregation through archetype buildings: France, Germany, Spain and the UK, *Building and Environment*, 81, 270-282.

Kavgic, M, Mavrogianni, A, Mumovic, D, Summerfield, A, Stevanovic, Z and Djurovic-Petrovic, M *(*2010) A review of bottom-up building stock models for energy consumption in the residential sector, *Building and Environment*, 45(**7**), 1683-1697.

van Kerkhoff, L (2014) Developing integrative research for sustainability science through a complexity principles-based approach, *Sustainability Science*, 9(**2**), 143-155.

Marzouk, M and El-Hawary, M (2017) Towards evaluation and prediction of building sustainability using life cycle behaviour simulation, *MATEC Web of Conferences*, 120, 1-7.

Mata, É, Kalagasidis, A S and Johnsson, F (2013) A modelling strategy for energy, carbon and cost assessments of building stocks, *Energy and Buildings*, 56, 100-108.

Österbring, M, Las Hera, E M, Thuvander, L, Mangold, M, Johnsson, F and Wallbaum, H *(*2016) A differentiated description of building-stocks for a georeferenced urban bottom-up building-stock model, *Energy and Buildings*, 120, 78-84.

Sterman, J D (2002) System dynamics: Systems thinking and modelling for a complex world, *In*: *ESD Working Papers; ESD-WP-2003-01.13-ESD Internal Symposium*, Massachusetts Institute of Technology. Engineering Systems Division

Thompson, B P and Bank, L C (2010) Use of system dynamics as a decision-making tool in building design and operation, *Building and Environment*, 45(**4**), 1006-1015.

Zou, Y, Kiviniemi, A and Jones, S W (2017) A review of risk management through BIM and BIM-related technologies, Safety Science, 97, 88-98.

GLOBAL WARMING POTENTIAL OF CHINA'S MANUFACTURING INDUSTRY AND ITS IMPLICATION ON CONSTRUCTION

Peng Wu[1]

School of Design and the Built Environment, Curtin University, Kent Street, Bentley, Perth, WA 6102, Australia

China's manufacturing industry accounts for 57.5% of the national total energy consumption in 2014, thus becoming the single largest contributor to global climate change in China. This paper therefore aims to investigate the global warming potential of China's manufacturing industry based on a decomposition analysis. The results indicate that since 1994, the global warming potential of China's manufacturing industry has increased by 5.3 billion-ton CO2e. The increase in production volume is the single biggest factor leading to the increase, with an estimated value of 11.8 billion-ton CO2e. At the meantime, effective strategies to reduce the global warming potential of the industry include lower energy intensity, cleaner industry structure, cleaner fuel consumption structure and lower emission factors of fuel, with estimated reduction values of 4.6 billion ton, 1.1 billion ton, 0.7 billion ton and 31.3 million ton respectively. As for the implications on the construction industry, while emission factors and energy intensity are believed to be useful in reducing the global warming potential of the construction industry, the usefulness of development density and fuel mix should be further investigated.

Keywords: global warming, carbon dioxide, manufacturing, decomposition analysis

INTRODUCTION

Global climate change has been recognized as one of the biggest environmental impacts and it is commonly agreed that global climate change is mainly caused by human activity (Wu *et al.,* 2017). Intergovernmental Panel on Climate Change (IPCC) (2013) stated that the atmospheric carbon emissions concentration has been relatively stable before the industrial era. The CO2 concentration is currently at 408.8 parts per million (ppm) (June 2017), which is much higher than the average CO2 concentration in the past two centuries (around 280 ppm) (American Chemical Society, 2017). Global climate change can cause serious disruption to human development in terms of rising sea level rise (Meehl *et al.,* 2005), extreme weather events and food security (Lobell *et al.,* 2008). Consequently, there is a growing interest to manage carbon emissions globally (Wang *et al.,* 2018).

According to the Boden *et al.,* (2017), China is the largest carbon dioxide emitters since 2008. Fossil fuel combustion and industrial processes of China account for almost 30% of global carbon dioxide emissions (Boden *et al.,* 2017). According to the National Bureau of Statistics of China (2016), the manufacturing industry accounts

[1] peng.wu@curtin.edu.au

Wu, P (2019) Global Warming Potential of China's Manufacturing Industry and Its Implication on Construction *In:* Gorse, C and Neilson, C J (Eds) *Proceedings of the 35th Annual ARCOM Conference,* 2-4 September 2019, Leeds, UK, Association of Researchers in Construction Management, 445-454.

for 57.5% of the national total energy consumption in 2014, thus becoming the single largest contributor to global climate change in China. Ensuring a sustainable development of the manufacturing industry is of critical importance for China to meet the target of 40%-45% emissions reduction from 2005 to 2020 (China Climate Change Info-Net, 2016).

Hammond and Norman (2012) pointed out that the past trend of carbon emissions is useful to understand the current situation and make future decisions on achieving carbon reduction target. As such, many studies have been conducted on analysing how the level of carbon emissions has been changing over the past few decades. For example, Xu *et al.,* (2014) investigated the influence of five factors, including energy structure, energy intensity, industry structure, economic output and population scale, on energy-induced carbon emissions of China. Similarly, Feng *et al.,* (2012) used structural decomposition analysis (SDA) to analyse the impact of five factors, including population, urbanization level, industrial structure, technology and household consumption behaviour on China's regional carbon emissions. It should be noted that as "factory of the world", China's manufacturing industry plays a significant role in achieving its reduction target. However, the manufacturing industry is characterized by its large variability related to the energy types and consumption ways (Hammond and Norman, 2012). As such, very limited studies have been conducted on analysing the influencing factors of the carbon emissions from China's manufacturing industry through decomposition analysis. Wan *et al.,* (2016) only investigated the equipment manufacturing industry in China and Liu *et al.,* (2015) investigated the influencing factors of China's 28 manufacturing subsectors using gross domestic product (GDP). It should be noted that there are several problems with previous decomposition analyses. Compared to GDP, value added, which involves the subtraction of cost of inputs, can better reflect physical production and does not have an issue of double counting (Hammond and Norman, 2012). In addition, the National Bureau of Statistics of China classifies the manufacturing industry into 29 subsectors. More importantly, methane (CH4) and nitrous oxide (N2O) have global warming potentials which are 28-36 and 265-298 times higher than that of carbon emissions (Qu *et al.,* 2011). It is therefore necessary to use global warming potential, which is a consistent evaluation criterion for climate change impact across different gases (Wang *et al.,* 2018).

This paper therefore aims to: 1) investigate the GWP of China's manufacturing industry from 1994 - 2014; and 2) evaluate the policy implications on the construction industry to achieve the reduction target, given the close relationship between the manufacturing industry and the construction industry. The construction industry uses various materials, the extraction and manufacturing of which have heavy impact on the emissions level. A close examination of the emissions from the manufacturing industry would therefore be able to help understand the emissions and patterns from the construction industry. More importantly, China's manufacturing industry is one of the first industries where heavy regulations related to emissions reduction are in place. The examination of the industry would benefit the construction industry which is now facing increasing pressure to achieve emission reduction.

RESEARCH METHOD

Factors Influencing the GWP of China's Manufacturing Industry

The changes of energy-related emissions are usually driven by multiple factors such as energy consumption, energy intensity, energy structure, economic output, population,

investment, and other factors (Cansino *et al.,* 2015). The manufacturing industry is one of the most energy intensive industries that produce emissions (Akbostancı *et al.,* 2011; Wang *et al.,* 2014). The influencing factors of carbon emissions from the manufacturing industry have been studied by a few researchers from different countries.

One of the most commonly adopted influencing factors is production. It refers to the value added of manufacturing output. This factor can best track the physical production of products. In addition, the factors is widely reported and does not have the issue of double counting (Hammond and Norman, 2012). Energy intensity refers to the average energy consumption per unit of value added. The factor represents the cost of converting energy into value added. High energy intensity indicates a high cost of the conversion process. Industry structure represents the composition of the manufacturing industry. As some subsectors, e.g. smelting and pressing of ferrous metals, are energy intensive, an increase in the relative size of these subsectors will lead to an increase in emissions. Fuel mix also plays an important role. Different fuels have different calorific values and emission factors. For example, the calorific value of diesel is two times of coal, reported by China's National Standard GB/T 2589-2008: General Rules for Comprehensive Energy Consumption Calculation. The emission factor of different fuel types may change. The emission factors of fuel are normally fixed in previous studies (Hammond and Norman, 2012). The emission factor of electricity normally changes, because the composition of power generation changes and the process of coal-fired electricity generation improves every year. Some important sources of carbon emissions, such as the use of aluminium and glass, was excluded from previous studies in the construction industry (Wu *et al.,* 2019). Wu *et al.,* (2019) argued that such exclusion can affect the accuracy of the carbon analysis and subsequent decision making related to emission reduction. It is therefore important to understand the emission levels of the manufacturing industry to decide which sectors should be included in the analysis of the construction industry.

Modelling Approach

Index decomposition analysis (IDA) based on statistical data and structural decomposition analysis (SDA) which employs input-output tables are the two common methodologies used by researchers to study drivers of changes in energy-related emissions (Wang *et al.,* 2017). Compared to SDA, IDA has the advantages of simplicity and the availability of data (Hammond and Norman, 2012). All IDA techniques are generally divided into two categories: technique linked to Divisia index and technique linked to Laspeyres index (Howarth *et al.,* 1991). Generally speaking, the Divisia index technique is preferred because it is more scientific (Ang, 2004). Although the Laspeyres index technique is easier to understand and commonly used by energy researchers in the 1990s, this technique often gives a large residual, thus affecting the estimated effects. Therefore, the Divisia index technique is adopted in this study as it delivers perfect decomposition whereby no unexplained residual term exist in the results. The Divisia index techniques can be further divided into two groups: namely multiplicative decomposition (Ang and Liu, 2001) and additive decomposition (Ang *et al.,* 1998). The arithmetic mean Divisia index methods (AMDI) and the log mean Divisia methods (LMDI) (Ang *et al.,* 1998) are widely applied by both groups. Although the formulae of AMDI is simpler compared to LMDI, increasing number of studies (Akbostancı *et al.,* 2011) selected LMDI to conduct decomposition analysis for emissions changes as LMDI gives perfect decomposition and can handle the value zero in the data set (Ang *et al.,* 1998). Based

on these literature review, LMDI is herein selected as the decomposition analysis technique in this study.

Mathematical Representation of the GWP

The GHGs (including CO2, CH4 and N2O) of energy consumption (excluding electricity consumption) are calculated based on CO2 equivalent. Considering that CH4 and N2O have higher GWP than CO2, the GHG of the manufacturing industry can be calculated by:

$$GHG_{Manufacturing} = CO_{2,Manufacturing} + 23\ CH_{4,Manufacturing} + 296\ N_2O_{Manufacturing} \quad (1)$$

The National Bureau of Statistics of China reports the annual energy consumption by sector in the China Statistics Yearbook. The GHG emissions of the annual energy consumption are calculated by:

$$CO_{2,t} = \sum_{i=1}^{29}\sum_{j=1}^{8} CO_{2,ij,t} = \sum_{i=1}^{29}\sum_{j=1}^{8} E_{ij,t} \times EF_{CO_2,j} \times V_j \quad (2)$$

$$CH_{4,t} = \sum_{i=1}^{29}\sum_{j=1}^{8} CH_{4,ij,t} = \sum_{i=1}^{29}\sum_{j=1}^{8} E_{ij,t} \times EF_{CH_4,j} \times V_j \quad (3)$$

$$N_2O_t = \sum_{i=1}^{29}\sum_{j=1}^{8} N_2O_{ij,t} = \sum_{i=1}^{29}\sum_{j=1}^{8} E_{ij,t} \times EF_{N_2O,j} \times V_j \quad (4)$$

where:

CO2, t, CH4, t, and N2Ot refer to the total CO2, CH4 and N2O emissions in year t;

i refers to the sectors within the manufacturing industry following the industry classification codes in the China Statistical Yearbook. A total of 29 sub-sectors are recorded;

j refers to the types of energy consumption, including (raw coal, coke, crude oil, gasoline, kerosene, diesel oil, fuel oil, natural gas and electricity);

Eij,t refers to the energy consumption of source j from sector i in year t;

$EF_{CO_2,j}$, $EF_{CH_4,j}$ and $EF_{N_2O,j}$is the emission factors of energy source j on a net calorific basis reported by IPCC (2006); and

Vj is the Chinese specific low-calorific value of energy source j (excluding electricity), reported in the National Standard GB/T 2589-2008: General Rules for Comprehensive Energy Consumption Calculation.

Decomposition model

This study uses LMDI method to analyze the contribution of each influencing factor to the GWP of China's manufacturing industry. LMDI uses a logarithmic weight function instead of arithmetic weight function.

Following the LMDI method, the GWP of China' manufacturing industry can be calculated by:

$$GWP = \sum_i\sum_j GWP_{ij} = \sum_i\sum_j Q\frac{Q_i}{Q}\frac{E_i}{Q_i}\frac{E_{ij}}{E_i}\frac{GWP_{ij}}{E_{ij}} = \sum_i\sum_j Q \cdot IS_i \cdot EI_i \cdot FM_{ij} \cdot EF_{ij}$$

(5)

where:

Q is the value added of the manufacturing industry; Qi is the value added of the subsector i; Ei is the energy consumption of subsector i; Eij is the fuel consumption

from source j in subsector i; GWPij is the global warming potential of fuel source j of subsector i; ISi is the activity share of subsector i in terms of value added; EIi is the energy intensity of subsector i; and FMij is the fuel mix in subsector i.

Consequently, the change in GWP of China's manufacturing industry can be decomposed into the changes of the five influencing factors, by:

$$\Delta GWP = \Delta GWP_Q + \Delta GWP_{IS} + \Delta GWP_{EI} + \Delta GWP_{FM} + \Delta GWP_{EF} \quad (6)$$

$$\Delta GWP_Q = \sum_{i=1}^{28}\sum_{j=1}^{9} L\left(GWP_{ij}^T, GWP_{ij}^0\right) \ln\frac{Q^T}{Q^0} = \sum_{i=1}^{28}\sum_{j=1}^{9} \frac{GWP_{ij}^T - GWP_{ij}^0}{\ln GWP_{ij}^T - \ln GWP_{ij}^0} \ln\frac{Q^T}{Q^0} \quad (7)$$

$$\Delta GWP_{IS} = \sum_{i=1}^{28}\sum_{j=1}^{9} L\left(GWP_{ij}^T, GWP_{ij}^0\right) \ln\frac{IS_i^T}{IS_i^0} = \sum_{i=1}^{28}\sum_{j=1}^{9} \frac{GWP_{ij}^T - GWP_{ij}^0}{\ln GWP_{ij}^T - \ln GWP_{ij}^0} \ln\frac{IS_i^T}{IS_i^0} \quad (8)$$

$$\Delta GWP_{EI} = \sum_{i=1}^{28}\sum_{j=1}^{9} L\left(GWP_{ij}^T, GWP_{ij}^0\right) \ln\frac{EI_i^T}{EI_i^0} = \sum_{i=1}^{28}\sum_{j=1}^{9} \frac{GWP_{ij}^T - GWP_{ij}^0}{\ln GWP_{ij}^T - \ln GWP_{ij}^0} \ln\frac{EI_i^T}{EI_i^0} \quad (9)$$

$$\Delta GWP_{FM} = \sum_{i=1}^{28}\sum_{j=1}^{9} L\left(GWP_{ij}^T, GWP_{ij}^0\right) \ln\frac{FM_i^T}{FM_i^0} = \sum_{i=1}^{28}\sum_{j=1}^{9} \frac{GWP_{ij}^T - GWP_{ij}^0}{\ln GWP_{ij}^T - \ln GWP_{ij}^0} \ln\frac{FM_i^T}{FM_i^0} \quad (10)$$

$$\Delta GWP_{EF} = \sum_{i=1}^{28}\sum_{j=1}^{9} L\left(GWP_{ij}^T, GWP_{ij}^0\right) \ln\frac{EF_i^T}{EF_i^0} = \sum_{i=1}^{28}\sum_{j=1}^{9} \frac{GWP_{ij}^T - GWP_{ij}^0}{\ln GWP_{ij}^T - \ln GWP_{ij}^0} \ln\frac{EF_i^T}{EF_i^0} \quad (11)$$

The outputs of Equations 7-11 represent the contribution of the influencing factors of output, industry structure, energy intensity, fuel mix, and emission factor respectively.

RESULTS

Energy-Related GWP of China's Manufacturing Industry

The energy-related GWP of China' manufacturing industry and corresponding percentage of China's total GWP from 1994-2014 are shown in Figure 1(A). The GWP of China's manufacturing industry shows an upward trend from 2.31 billion t CO2e in 1994 to 8.71 billion t CO2e in 2014. The GWP growth from 2003-2004 has the largest growth rate of 22.17%. The contribution of China's manufacturing industry to the overall GWP decreases to the lowest of 48.11% in 2003. Its contribution has been increasing since then and sits at 54.77% in 2014, demonstrating the importance of China's manufacturing industry to the country's overall GWP. The contributions of CO2, CH4 and N2O to China' GWP are fairly stable, at around 99.55%, 0.15% and 0.30% respectively.

The top five subsectors (in terms of GWP contribution) in the manufacturing industry are presented in Figure 1(B). From 1994-1995, the top five subsectors are smelting and pressing of ferrous metals (22.99%-23.30%), petroleum processing and coking products (20.50%-21.50%), raw chemical materials and chemical products (15.97%-16.00%), non-metal mineral products (13.70%-13.63%), and textile (3.46%-3.30%). Starting from 1996, smelting and pressing nonferrous metals has taken over textile as the fifth largest manufacturing subsectors in terms of GWP contribution. From 1996-2014, the top five subsectors of GWP in manufacturing are petroleum processing and coking products (21.52%-29.00%), smelting and pressing of ferrous metals (22.71%-26.38%), raw chemical materials and chemical products (17.66%-13.14%), non-metal mineral products (13.55%-10.76%), and smelting and pressing of nonferrous metals (3.01%-6.20%).

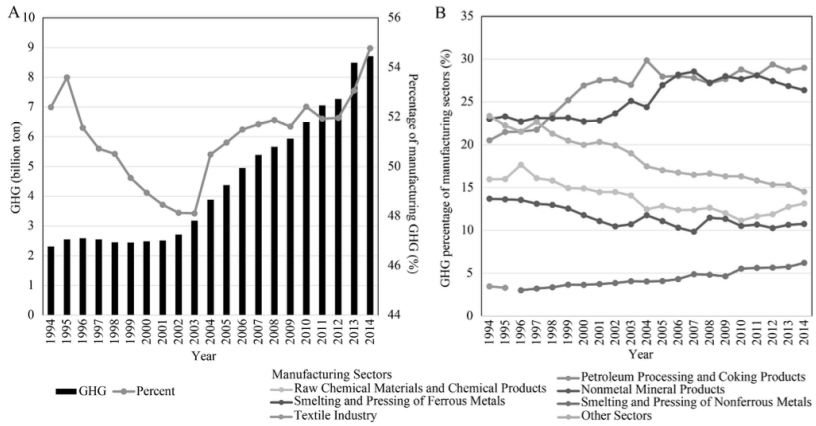


Figure 1: The GWP of China's manufacturing industry. (A) The GWP of China's manufacturing industry and its corresponding percentage of China's total GWP; (B) The top five manufacturing subsectors (in terms of GWP contribution) of China from 1994-2014.

The GWP of China' manufacturing industry has different pattern when compared with other industries, such as the construction industry. The carbon emissions of the construction industry reached the peak of 0.16 billion t in 2012. However, the magnitude of the GWP from the two industries varies significantly and it seems that the GWP of the manufacturing industry has not reached its peak in 2014. In addition, the manufacturing industry faces increasing pressure to manage its energy consumption and GWP as the government has announced that the annual growth of energy consumption cannot exceed 3.5% from 2015-2020 (Lu *et al.,* 2016). However, the average growth rate of energy consumption from 2010-2014 is 8.33% (see Figure 2).

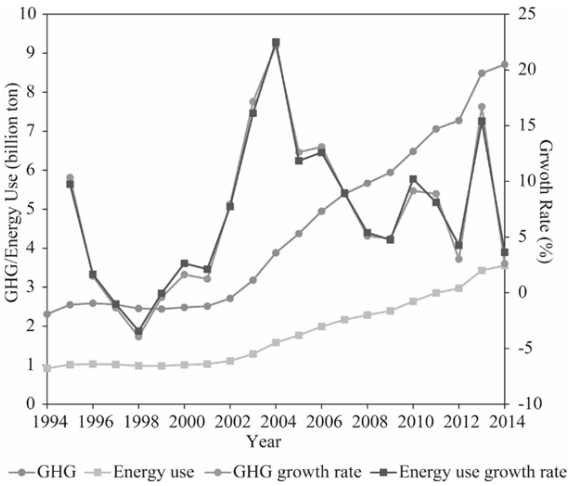


Figure 2: The growth rate of annual GWP and energy consumption of China's manufacturing industry from 1994-2014

Decomposition Results

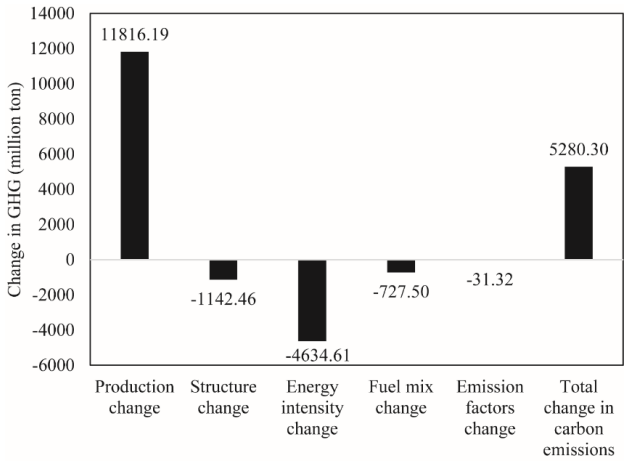
Figure 3 shows the results of the decomposition analysis from 1994-2014 in a cumulative way. From 1994-2004, the GWP of China's manufacturing industry has increased by 5280.30 million tCO2e. Production change because of increased value added is the largest contributor to the increase of GWP, accounting for 123% of the increase. On the other hand, energy intensity, industry structure, fuel mix and emission factor all contribute to the reduction of GWP, at 4643.61, 1142.46, 727.50 and 31.32 million tCO2e respectively.

Figure 4 shows the results of the decomposition analysis at a yearly basis. Three most notable years with significant reduction of annual GWP can be identified, including 2007-2008, 2011-2012 and 2013-2014.

DISCUSSIONS

Influencing Factors of the GWP Change

The empirical results reveal that production change is the single largest contributor to the GWP of China's manufacturing industry. This is in accordance with China's economic growth over the analysis period. In order to offset such increase, a few strategies have proven to be effective. Reducing energy intensity, as an indicator of the average energy consumption per unit of value added, represents the most effective measure. Over the past 10 years (from 2004 to 2014), the energy intensity has reduced from 2531 g sce/usd to 784 g sce/usd, a 69% reduction. Other useful strategies include structure change, i.e. the shifting towards subsectors which utilise lower energy consumption. In addition, fuel mix is also a useful strategy through two improvement areas, i.e. relying less on coal-fired electricity generation and the improvement of coal-fired electricity generation in terms of energy efficiency. According to Wu *et al.,* (2019), the percentage of coal-fired electricity generation in China is gradually decreasing from 82.33% in 2000 to 74.24% in 2015. In addition, the standard coal consumption for producing 1 kwh electricity is reduced from 392 g sce to 315 g sce from 2000 to 2015.



Implications for the Construction Industry

The GWP pattern of the manufacturing industry does provide some useful insights on the GWP pattern of the construction industry. First of all, it is expected that emission factors should be effective in reducing the GWP of the construction industry. Although emission factors of majority of the fuel, e.g. coal and diesel, remain unchanged, the emission factor of electricity, which is also an important source of energy in the construction industry, is gradually reducing. However, there are a few concerns that can only be addressed when further analysis is conducted in the construction industry. The most important difference between the construction industry and the manufacturing industry is that the construction industry does not have a detailed list of sub-sectors as the manufacturing industry.

Figure 3: The cumulative contribution of the five influencing factors towards the GWP of China's manufacturing industry.

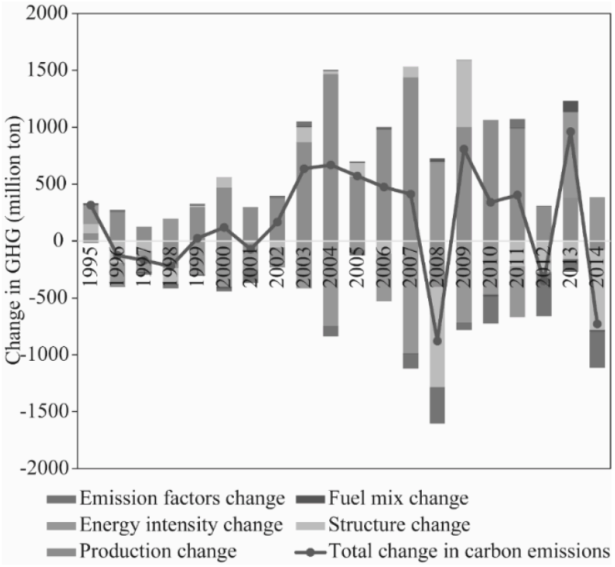


Figure 4: The yearly contribution of the five influencing factors towards the GWP of China's manufacturing industry

Therefore, it may be difficult to investigate the impact of structure change. One useful way is to analyse the phases of the construction industry, including extraction and use of raw materials, construction and operation. As new construction has slowed down over the past few years, it would be interesting to investigate whether a focus towards operation can help reduce the GWP of the industry. The next speculation is that fuel mix will not play as an important role in construction as it is in manufacturing. A preliminary investigation shows that there is a significant increase in the use of coals for building operation from 2000 to 2015. Some other indicators may also be interesting to be investigated. For example, how significant is the impact of urbanization on the GWP of the construction industry and is the increase in development density effectively effective to reduce GWP, because there is a common belief that low-density suburban development is more energy intensive.

CONCLUSIONS

The main contribution of this study is to analyse the influence factors of the GWP of China's manufacturing industry. A total of five influence factors, including production, energy intensity, industry structure, fuel mix and emission factors, are investigated. The results show that the increase in production volume, in terms of value added, is the single most important factor that leads to an increase of GWP in this industry. Other factors are proven to be effective in reducing the GWP from 1994-2014. The results also provide some useful insights into how the GWP of the construction industry should be analysed and managed. Aluminium and glass, representing a significant portion of the industry's emissions, should not be overlooked. In addition, while emission factors and energy intensity are believed to be useful in reducing the GWP of the construction industry, the usefulness of development density and fuel mix should be further investigated.

REFERENCES

Akbostancı, E, Tunç, G İ and Türüt-Aşık, S (2011) CO2 emissions of Turkish manufacturing industry: A decomposition analysis, *Applied Energy*, 88(**6**), 2273-2278.

American Chemical Society (2017) *What Are the Greenhouse Gas Changes Since the Industrial Revolution*? Available from https://www.acs.org/content/acs/en/climatescience/greenhousegases/industrialrevolution.html [Accessed 10/07/2017].

Ang, B W (2004) Decomposition analysis for policymaking in energy: Which is the preferred method? *Energy Policy*, 32(**9**), 1131-1139.

Boden, T A, Marland, G and Andres, R.J (2017) *National CO2 Emissions from Fossil-Fuel Burning, Cement Manufacture and Gas Flaring: 1751-2014*, Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, U.S Department of Energy.

Cansino, J M, Sánchez-Braza, A and Rodríguez-Arévalo, M L (2015) Driving forces of Spain′s CO 2 emissions: A LMDI decomposition approach, *Renewable and Sustainable Energy Reviews*, 48, 749-759.

China Climate Change Info-Net First Biennial Update Report on Climate Change (2016) Available at http://www.ccchina.gov.cn/archiver/ccchinacn/UpFile/Files/Default/20170124155928346053.pdf [Accessed 17/08/2017].

Diakoulaki, D and Mandaraka, M (2007) Decomposition analysis for assessing the progress in decoupling industrial growth from CO 2 emissions in the EU manufacturing sector, *Energy Economics*, 29(**4**), 636-664.

Hammond, G P and Norman, J B (2012) Decomposition analysis of energy-related carbon emissions from UK manufacturing, *Energy*, 41(**1**), 220-227.

Howarth, R B, Schipper, L, Duerr, P A and Strøm, S (1991) Manufacturing energy use in eight OECD countries: Decomposing the impacts of changes in output, industry structure and energy intensity, *Energy Economics*, 13(**2**), 135-142.

IPCC (2013) *Climate Change 2013: The Physical Science Basis*. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, T F Stocker, D Qin, G-K Platter, M M B Tignor, S K Allen, J Boschung, A Nauels, Y Xia, V Bex and P M Midgley (Eds). Cambridge: Cambridge University, 1535.

Jeong, K and Kim, S (2013) LMDI decomposition analysis of greenhouse gas emissions in the Korean manufacturing sector, *Energy Policy*, 62, 1245-1253.

Liu, Q, Liu, S and Kong, L (2015) Decomposition and decoupling analysis of energy-related carbon emissions from China manufacturing, *Mathematical Problems in Engineering*, 2015(**1**)1-9.

Lobell, D B, Burke, M B, Tebaldi, C, Mastrandrea, M D, Falcon, W P and Naylor, R L (2008) Prioritizing climate change adaptation needs for food security in 2030, *Science*, 319(**5863**), 607-610.

Lu, Y, Cui, P and Li, D (2016) Carbon emissions and policies in China's building and construction industry: Evidence from 1994 to 2012, *Building and Environment*, 95, 94-103.

Meehl, G A, Washington, W M, Collins, W D, Arblaster, J M, Hu, A, Buja, L E, Strand, W G and Teng, H (2005) How much more global warming and sea level rise? *Science*, 307(**5716**), 1769-1772.

National Bureau of Statistics of China (2016) *China Statistical Yearbook 2016*. Available from http://www.stats.gov.cn/tjsj/ndsj/2016/indexeh.htm [Accessed 17/08/2017].

Qu, X, Xiaoyu, Y and Zhang, X (2011) Life-cycle energy consumption and greenhouse gas emissions for electricity generation and supply in China, *Applied Energy*, 88(**1**), 289-297.

Ren, S, Yin, H and Chen, X (2014) Using LMDI to analyse the decoupling of carbon dioxide emissions by China's manufacturing industry, *Environmental Development*, 9, 61-75.

Wan, L, Wang, Z L and Ng, J C Y (2016) Measurement research on the decoupling effect of industries' carbon emissions-based on the equipment manufacturing industry in China, *Energies*, 9(**11**), 921.

Wang, H, Ang, B W and Su, B (2017) Assessing drivers of economy-wide energy use and emissions: IDA versus SDA, *Energy Policy*, 107, 585-599.

Wang, W, Liu, X, Zhang, M and Song, X (2014) Using a new generalized LMDI (logarithmic mean Divisia index) method to analyse China's energy consumption, *Energy*, 67, 617-622.

Wang, T, Wang, J, Wu, P, Wang, J, He, Q and Wang, X (2018) Estimating the environmental costs and benefits of demolition waste using life cycle assessment and willingness-to-pay: A case study in Shenzhen, *Journal of Cleaner Production*, 172, 14-26.

Wu, P, Song, Y, Shou, W, Chi, H, Chong, H Y and Sutrisna, M (2017) A comprehensive analysis of the credits obtained by LEED 2009 certified green buildings, *Renewable and Sustainable Energy Reviews*, 68, 370-379.

Wu, P, Song, Y, Zhu, J and Chang, R (2019) Analyzing the influence factors of the carbon emissions from China's building and construction industry from 2000 to 2015, *Journal of Cleaner Production*, 221, 552-566.

Xu, S.C, He, Z.X and Long, R.Y (2014) Factors that influence carbon emissions due to energy consumption in China: Decomposition analysis using LMDI, *Applied Energy*, 127, 182-193.

Xu, S.C, Zhang, L, Liu, Y.T, Zhang, W.W, He, Z.X, Long, R.Y and Chen, H (2017) Determination of the factors that influence increments in CO_2 emissions in Jiangsu, China using the SDA method, *Journal of Cleaner Production*, 142, 3061-3074.

SUSTAINABLE CONSTRUCTION AND RESIDENTIAL BUILDING DEVELOPERS IN MALAYSIA: FACTORS AFFECTING THE ADOPTION

Noorsaidi Mahat[1], Joseph H M Tah and Christos Vidalakis

School of the Built Environment, Faculty of Technology, Design and Environment, Oxford Brookes University, Oxford, OX3 0GB, UK

The adoption and implementation of Sustainable Construction has been one of the main challenges facing the construction industry for the last three decades. The issue has attracted global attention with many governments and organizations developing codes and frameworks to encourage and enforce the adoption of Sustainable Construction. However, current evidence suggests that companies and individuals are struggling to commit to Sustainable Construction and implement the suggested policies. This paper explores from the Malaysian residential building developer's perspective, the barriers and external drivers influencing the adoption of sustainable construction in Malaysia. A comprehensive literature survey is carried out to develop a theoretical link between sustainable construction and identified factors. This was followed by a structured questionnaire survey among 365 Developer company registered with the REHDA (Real Estate and Residential Building Developers 'Association Malaysia). 103 responses were received, 101 considered valid for analysis. Findings from the study revealed financial support (Incentives/tax rebates/subsidies, high profit margin), legislative and building regulation and availability of rating system. E.g. Green Building Index (GBI) are the key external drivers. Besides, high initial cost and investment, insufficient initiatives and support by government in term of tax rebates/subsidies/incentives and lack of improvement of legislation, building code and byelaws are the crucial barrier to the sustainable construction adoption. The study suggests government support in term of financial incentives, change in legislation and creation of awareness can promote the adoption and at the same time can provide barriers mitigation.

Keywords: sustainable construction, barriers, external drivers, adoption

INTRODUCTION

Residential buildings are one of the largest consumers of energy and water as well as producers of emissions and waste. During operation they consumes 32% of the world's renewable and non-renewable resources, 12% of available water and 40% of produced energy, while generating 40% of global CO2 emissions (GBCA, 2013). Apart from the potential to improve the environmental performance of buildings, Sustainable Construction (SC) has been associated with numerous benefits including increased property value, improved occupant productivity and better corporate image (Hyland *et al.,* 2013). However, even though SC seems to be an attractive business proposition for housing developers, adoption has been slow. Indeed, as pointed out by Thomson, (2001) delivering sustainability remains a challenge partly due to a range of

[1] 15110098@brookes.ac.uk

Mahat, N, Tah, J H M and Vidalakis, C (2019) Sustainable Construction and Residential Building Developers in Malaysia: Factors Affecting the Adoption *In:* Gorse, C and Neilson, C J (Eds) *Proceedings of the 35th Annual ARCOM Conference,* 2-4 September 2019, Leeds, UK, Association of Researchers in Construction Management, 455-463.

traditional, cultural and structural barriers such as the lack of integration between the different project stages, poor collaboration between the various professions in the project team and lowest-cost focused procurement (Sodagar, (2008), Häkkinen, (2011), Razali, (2015). The latter i.e. cost concerns have been cited by many researchers as the most important barrier to sustainable construction.

To encourage and enforce the adoption of SC many governments and organizations across the globe have proposed and implemented a series of measures and strategies. Malaysia has one of the best sets of environmental legislations, comparable even with those of developed countries Sani, (2007), indeed, a number of sustainable development frameworks and policies are in place, deployed to reduce and overcome sustainability issues. However, current evidence suggests that companies and individuals are struggling to commit to SC. As shown by Haron, (2005) the level of knowledge and awareness of environment issues and sustainability aspects among Malaysian residential developers has been particularly low. This indicates that the concerted efforts for promoting SC have not had the anticipated impact.

Sustainable construction is an important way to realize the sustainable development of construction industry. At present, many scholars have studied sustainable development and sustainable construction in the built environment, several definitions on sustainable construction has been introduced. Therefore, the final definition of Sustainable Construction in this paper is: In the residential building industry, it is the general term of the application, practices, innovation, technologies, products, approach, measures, initiatives, processes and technical means to be employed to accomplish the aim of "energy saving, water saving, material saving, land saving, and environmental protection" during the whole life cycle of the construction.

The majority of the studies looking at SC adoption have focused on design for sustainability Nilashi (2015), sustainability performance (Sim, 2015) and sustainability related technological challenges (Diyana, 2013). It is evident that further research is required into the factors affecting the decision of residential developers to embrace SC in the context of Malaysia. Therefore, this study explores residential building developer's perspective by looking at the barriers and external drivers influencing the adoption of sustainable construction in Malaysia.

LITERATURE REVIEW

Residential Building Developers and Sustainable Construction

Residential buildings are one of the largest consumers of energy and water as well as producers of emissions and waste. In Malaysia, the demand for houses is expected to be over 30 million in the year 2020, highlighting serious housing issues (Ajzen, 1991). The industry has been using conventional methods for many years, where environmental issues were not a major concern. With greater urbanisation and more projects on hillside and coastal areas, Malaysia is facing multiple environmental problems such as an increase in construction waste material generation (Ajzen, 2006), soil erosion, deforestation and landslides (Kraft *et al.,* 2005), water pollution and ecosystem disruption (Armitage, 2001) and many more. There are some buildings which claimed to be sustainable but were not classified as a sustainable building because they do not meet certain requirements. Houses being built in the past decades did not meet the essential criteria of sustainability and contributing to energy inefficiency.

Also, In Malaysia, residential buildings consume 15 per cent of total energy and are a key contributor to greenhouse gas emissions Tornatzky, 1982). Furthermore, up to date in 2015, there is total of 8,028 local building projects, 121 from it is Green Building Index (GBI) registered, but less than two per cent of eligible projects are assessed with building rating systems such as the GBI, and even among those assessed, less than 50 percent have been rated. Furthermore, this study will be a focus on developers' view because of their crucial role in the green application. Equivalent to project client, the developer dictates the course of the projects and are regarded as key decision makers and play an important role to determine the extent of sustainable approach for a particular project. Besides, they were projected initiators are having prevailing influence over the overall project direction. Also, their positions are strategic to ensure green practices are effectively applied.

Barriers Towards Sustainable Construction

Despite the numerous benefits claimed to be associated with sustainable construction, adopting such practices has its barriers. Thomson and El-Haram (2011) explained that delivering sustainability in practice remains a challenge partly due to a range of traditional cultural and structural barriers such as the lack of integration between the different project stages and professions in the project team. Zhou and Lowe (2003) argue that the promotion of sustainable construction faces several economic challenges due to poor understanding of economic benefits that can be achieved. Even though there are high investment costs for sustainable construction projects compared with traditional building practices (Häkkinen and Belloni, 2011), however, this can be addressed by utilizing the whole life cycle costing technique, moving from cost to value and from short-term to long-term cost perspectives (Al-Yami and Price, 2006). Additional construction cost has been cited by many researchers as the most current barrier to the implementation of sustainable construction (Sodagar and Fieldson, 2008; Hakkinen and Belloni, 2011). This common perception that sustainable construction is more expensive regarding capital costs compared to efficient mainstream buildings is a significant challenge to the adoption of sustainable construction (Zhou and Lowe, 2003). Moreover, the focus on price in procuring construction products and services is also hindering the journey towards sustainable construction (Adetunji *et al.,* 2003; Sodagar and Fieldson, 2008; Häkkinen and Belloni, 2011).

In a qualitative study by Williams and Dair (2007) involving five case studies of completed developments in England, it was identified that there were a number of barriers to sustainable construction practices, including; lack of consideration of sustainability measures by stakeholders, not required by clients, real and perceived costs and inadequate expertise and powers. The complex and fragmented nature of the construction industry is suspected to be another reason there is a tendency to resist changes leading towards sustainability. Sustainable construction projects require close working interaction with all the project team from design to completion stage (Riley *et al.,* 2003; Häkkinen and Belloni, 2011). Most construction organizations concerned with the implementation of sustainable practices have the perception that it will result in increased risks, difficulties in obtaining financial support and the lack of awareness of market value (Zhou and Lowe, 2003). The construction industry is client driven and, therefore, plays a significant role in the adoption of sustainable construction. The challenge is that lack of client awareness and demand for sustainable building (Pitt *et al.,* 2009) will affect the agenda towards sustainability.

Construction organizations should, therefore, be proactive in offering sustainable services and products to prospective clients (Berry and McCarthy, 2011).

Drivers of Sustainable Construction

In considering the effectiveness of the drivers that have been implemented to achieve sustainable construction practices in developing countries, it would perhaps be wise to people's moral views towards the environment and also the process of change. The following have been identified as key drivers, Ethics and behavioural change and Legislation and regulation.

Ethics is the branch of philosophy that investigates morality and the ways of thinking that guide human behaviour. The philosophy of ethics requires that people take a step back from experience and reflect critically on it. Steg and Vlek (2009) suggested that when the environmental behaviour has been selected and its casual factors identified, intervention strategies can be targeted on those factors. Also, Steg and Vlek (2009) note that economic analysis in ethics rests on a serious misunderstanding between 'wants' or 'preferences' and 'beliefs' or 'values.' However, sustainable economics offer a different way to view about economics and the environment as sustainable economics is concerned with the resources rate flowing through the economy (Dyllick and Hockerts 2002). Therefore, it makes sense to develop a sustainable economic system that uses the resources at the rate the earth can sustain if human realizes natural resource originate from the earth.

Cocklin and Blunden (1998) suggested that regulatory analysis and regulation theory provide appropriate foundations for the analysis of the environmental problem and encourage firms to invest in green technologies. Tam *et al.,* (2006) and Fraj-Andres (2009) indicated that fines and penalties for non-compliance with regulations will lead to more cautious attitude to environmental compliance. Recent evidence (Jardin, 2009) provide a different view that environmental regulations go too far and mentioning that governments fail to consider economics or whether the social overall benefit provided may be worth the 'cost' to the environment. Stricter environment policies are needed as drivers. From the above review, it can be observed that sustainable construction in developing countries will be based on best practices which emphasize long-term affordability, quality, and efficiency.

RESEARCH METHODOLOGY

The study sought to explore from the Malaysian developer's perspective, the barriers and drivers influencing the adoption of sustainable construction in Malaysia. To attain these objectives, structured questionnaires involving closed-ended queries were distributed to developers belonging to the REHDA (Real Estate and Residential Building Developers 'Association Malaysia) within 365 registered developers' company. The 365 questionnaires were distributed via emails to the registered developers. A total of 103 responses were received of which 101 were deemed valid for analysis after data screening, thus representing 28% response rate. Data from the survey was analysed by percentages and mean score rankings.

Table 1: Ranking of perceived barriers of sustainable construction adoption

No.	Perceived Barriers of Sustainable Construction Adoption	Mean	Standard Deviation	Ranking
1	High initial cost and investment	4.25	0.684	1
2	Insufficient initiatives & support by government in term of tax rebates/subsidies/incentives	4.22	0.743	2
3	Lack of improvement of legislation, Building code and byelaws	4.16	0.689	3
4	Lack of skilled tradesman for sustainable construction	4.14	0.749	4
5	Overlapping of roles among the government agencies	4.14	0.749	5
6	Lack of project team commitment	4.08	0.796	6
7	Insufficient skills about sustainability	4.08	0.794	7
8	Lack of consideration of supplier and manufacturer	4.07	0.778	8
9	Lack of buyer demand and understanding of sustainability	4.03	0.806	9
10	Lack of understanding of cost vs benefits in term of sustainable implementation	4.02	0.836	10
11	Slow government programs about sustainability	3.99	0.854	11
12	Lack of research and innovation about sustainability	3.99	0.853	12
13	Lack of research about existing success sustainable building projects	3.99	0.852	13
14	Lack of training of benefits and incentives on sustainable buildings	3.98	0.824	14
15	Limited of local sustainable technology	3.97	0.830	15
16	Limited of local sustainable materials	3.96	0.848	16
17	Lack of consideration of client	3.96	0.677	17
18	Increase in project cost and low profit margin	3.95	0.853	18
19	Sustainable construction technology requires special technical maintenance due to the complexity of the technology	3.93	0.852	19
20	Sustainable construction complexity (complicated technology and not easy to adopt)	3.93	0.851	20
21	Sustainable methods compromise ease of traditional methods	3.92	0.924	21
22	Limited company policies	3.91	0.694	22
23	Lack of public interest	3.91	0.981	23
24	Lack of awareness and knowledge among project team and contractors on sustainability	3.89	0.904	24
25	Lack of education of benefits and incentives on sustainable buildings	3.88	0,909	25
26	Lack of financial resources to address sustainability	3.87	1.083	26
27	Lack of public awareness understanding sustainability	3.84	0.924	27
28	High cost of green materials and technology	3.79	1.052	28
29	Difficult to understand the use of green Contract requirement/procurement practices	3.78	0.996	29
30	Lack of success sustainable projects using sustainable technology to give an example	3.75	1.126	30
31	Risk of unforeseen cost	3.61	1.095	31
32	Inability of sustainable construction imported technology advance testing	3.53	1.162	32

The second part presented the identified barriers and drivers to sustainable construction and respondents were asked to rate the extent to which each of the barriers and drivers affects sustainable construction using a 5-point Likert scale. Here respondents were asked to indicate their degree of agreement with the barriers on the Likert scale of 5 = strongly agree, 4 = agree, 3 = fairly agree (average), 2 = disagree, 1 = strongly disagree. A factor with a mean score of 2.5 and above was considered significant for the purposes of this study.

FINDINGS AND DISCUSSION

Factors Affecting Sustainable Construction Adoption

At the beginning of research objectives of this study, the main issues stated is to identify the factors (barriers and drivers) that affect the adoption of sustainable construction practices in Malaysia. As such, the various responses regarding the drivers and barriers reported by respondents were ranked in terms of their percentages and mean score rankings.

The significant barriers of SC adoption that were identified in literature were listed on the questionnaire and respondents were asked to rank them on a scale of 1 to 5. The findings of the responds are presented in Table 1. It was observed that the most ranked barriers by developers is 'high initial cost and investment'. This recorded a mean of 4.25. This is in line with research conducted by (Abidin 2010), (Lim 2011) and (Samari, *et al.,* 2009) in which they claimed that to adopt the SC normally requires higher initial cost and investment.

Table 2: Ranking of external drivers of sustainable construction adoption

No.	Perceived External Drivers of Sustainable Construction Adoption	Mean	Standard Deviation	Ranking
1	Financial support (Incentives/tax rebates/subsidies, high profit margin)	4.28	0.665	1
2	Legislative and building regulation	4.18	0.669	2
3	Availability of rating system. E.g. Green Building Index (GBI)	4.03	0.793	3
4	Awareness and knowledge by top management	4.09	0.763	4
5	Availability of new and integrated technology and material	4.02	0.812	5
6	Availability and access to green products, materials and technology	3.99	0.818	6
7	Cost efficiency and risk	3.98	0.824	7
8	Availability of sustainable construction research funding	3.97	0.830	8
9	Client/buyer awareness and demand	3.96	0.734	9
10	Availability and supports of local suppliers and manufacturers	3.93	0.863	10
11	Stakeholder influence	3.90	0.866	11
12	Responding to competitor rivalry	3.88	0.972	12
13	Obtain more projects to maintain business	3.84	1.065	13
14	Availability of comprehensive Information and database	3.84	0.903	14
15	Company's Reputation and brand image	3.83	0.895	15
16	Portray moral obligation to protect the environment	3.75	1.014	16

The significant drivers of sustainable construction adoption that were identified in literature were listed on the questionnaire and respondents were asked to rank them on a scale of 1 to 5. The findings of the responds are presented in Table 2. It was observed that the most ranked driver by developers is 'financial support (Incentives/tax rebates/subsidies, high profit margin)'. This recorded a mean of 4.28. This is in line with research conducted by (Pitt *et al.,* 2009), in which they claimed that financial incentives are the leading significant driver for sustainable construction.

CONCLUSION AND FURTHER RESEARCH

The findings in this study provide information on the most ranked barriers and drivers in Malaysia. As observed from the study and mentioned earlier, most of the issues refers to financial incentives. This therefore suggest that the Government of Malaysia needs to focus on issues that promotes reduction of taxes and levies, on sustainable products (i.e. recyclable materials, etc.). In addition, it was also observed that construction professionals do not consider protection of the environment as a key issue in sustainable construction. However, protection of the environment is one of the main pillars of all professional of the built environment in Malaysia. This therefore suggests that there is a need for the government and stakeholders to focus on methods that ensures that construction professional value the environment. There is a need for further investigation on how various factors are related. In other words, inferential statistical methods must be used in the future to determine whether there is a correlation and correlation relationship between the various constructs and the identified variables. Such information will provide information on how to promote sustainable construction practices in Malaysia. This means that with information about the most appropriate variables any information about the relationship between the variables will provide information about the variables that need to be promoted at another to trigger other variables that will lead to the expedition of adoption and implementation of sustainable practice in Malaysia.

ACKNOWLEDGEMENT

This research is part of an ongoing PhD Project and was supported by Universiti Teknologi MARA. The authors are grateful to people who helped undertake the research and improve this article. The Authors would also like to thank the editors and reviewers for their insightful comments on this research

REFERENCES

Abidin, N Z (2010) Investigating the awareness and application of sustainable construction concept by Malaysian developers, *Habitat International*, 34(**4**), 421-426.

Abidin, N Z and Afandi, N D (2015) Exploring developers' expectations on green construction, *Advances in Environmental Biology*, 75-79.

Adetunji, I, Price, A, Fleming, P and Kemp, P (2003) Sustainability and the UK construction industry: A review, *Engineering Sustainability*, 156(**4**),185-199.

Ajzen, I (1991) The theory of planned behaviour, *Organizational Behaviour and Human Decision Processes*, 50(**2**), 179-211.

Ajzen, I (2006) The theory of planned behaviour, *Organizational Behaviour and Human Decision Processes*, 50(**2**), 179-211.

Ajzen, I and Fishbein, M (1980) *Understanding Attitudes and Predicting Social Behaviour*. London: Pearson.

Armitage, C J and Conner, M (2001) Efficacy of the theory of planned behaviour: A meta-analytic review, *British Journal of Social Psychology*,40(**4**), 471-499.

CIDB (2007) *Construction Industry Master Plan Malaysia 2006-2015*. Kuala Lumpur Construction Industry Development Board Malaysia.

Cocklin, C and Blunden, G (1998) Sustainability, water resources and regulation, *Geoforum*, 29, 51-68.

Diyana, A N and Abidin, N Z (2013) Motivation and expectation of developers on green construction: A conceptual view, *Proceedings of World Academy of Science, Engineering and Technology, 2013: World Academy of Science, Engineering and Technology* (WASET), 247.

Dyllick, T, and Hockerts, K (2002) Beyond the business case for corporate sustainability, *Business Strategy and the Environment*, 11(**2**), 130-141.

Elias, E M and Lin, C K (2015) The empirical study of green buildings (residential) implementation: Perspective of house developers, *Procedia Environmental Sciences*, 28, 708-716.

Fraj-Andres, E, Martinez-Salinas, E, Matute-Vallejo, J (2008) Factors affecting corporate environmental strategy in Spanish industrial firms, *Business Strategy and the Environment*, 18(**8**), 500-514

Froese, T and Rankin, J (2011) *Strategic Roadmaps for Construction Innovation: Assessing the State of Research*. Doctoral Thesis, University of British Columbia, Canada

GBCA (2013) *Green Star Project Directory*, Green Building Council, Australia. Available from https://www.gbca.org.au/project-directory.asp Accessed 12/07/2019].

Häkkinen, T and Belloni, K (2011) Barriers and drivers for sustainable building, *Building Research and Information*, 39(**3**), 239-255.

Hall, B H and Khan, B (2003) *Adoption of New Technology*. Paper No. w9730. National Bureau of Economic Research

Haron, S A, Paim, L and Yahaya, N (2005) Towards sustainable consumption: An examination of environmental knowledge among Malaysians, *International Journal of Consumer Studies*, 29(**5**), 426-436.

Hyland, M, Lyons, R C and Lyons, S (2013) The value of domestic building energy efficiency - evidence from Ireland, *Energy Economics*, 40, 943-952.

Idris, N H, Ismail, Z and Hashim, H (2015) Towards a framework for promoting sustainable construction in Malaysia, *Jurnal Teknologi*, 76(**1**).

Joachim, O I, Kamarudin, N, Aliagha, G U and Ufere, K J (2015) Theoretical explanations of environmental motivations and expectations of clients on green building demand and investment, IOP Conference Series: Earth and Environmental Science, 23(**1**), 012010.

Kraft, P, Rise, J, Sutton, S and Røysamb, E (2005) Perceived difficulty in the theory of planned behaviour: Perceived behavioural control or affective attitude? *British Journal of Social Psychology*, 44(**3**), 479-496.

Nemoto, M C M O, Vasconcellos, E P G d and Nelson, R (2010) The adoption of new technology: Conceptual model and application, *Journal of Technology Management and Innovation*, 5(**4**), 95-107.

Nilashi, M, Zakaria, R, Ibrahim, O, Majid, M Z A, Zin, R M, Chugtai, M W, Abidin, N I Z, Sahamir, S R and Yakubu, D A (2015) A knowledge-based expert system for assessing the performance level of green buildings, *Knowledge-Based Systems*, 86, 194-209.

Razali, M N and Mohd Adnan, Y (2015) Sustainable property development by Malaysian property companies, *Property Management*, 33(**5**), 451-477.

Sahin, I (2006) Detailed review of Rogers diffusion of innovations theory and educational technology-related studies based on Rogers theory, *The Turkish Online Journal of Educational Technology*, 5(**2**).

Samari, M, Godrati, N, Esmaeilifar, R, Olfat, P and Mohd Shafiei, M. (2013) The investigation of the barriers in developing green building in Malaysia, *Modern Applied Science*, 7 (2).

Sani, S and Mohd Sham, A (2007) *Environmental Management in Malaysia: Changing Concerns and Approaches*. IMPAK, 3, 4-6.

Sieber, S and Valor, J (2008) *Criteria for Adopting Information and Communication Technologies*, PwC/IESE/ Business and Information Project (Ed. Pellicer, M).

Sieffert, Y, Huygen, J and Daudon, D (2014) Sustainable construction with repurposed materials in the context of a civil engineering-architecture collaboration, *Journal of Cleaner Production*, 67, 125-138.

Sim, Y L and Putuhena, F J (2015) Green building technology initiatives to achieve construction quality and environmental sustainability in the construction industry in Malaysia, *Management of Environmental Quality: An International Journal*, 26(**2**), 233-249.

Sodagar, B and Fieldson, R (2008) Towards a low carbon construction practice, *Construction Information Quarterly*, 10(**3**), 101-108.

Steg, L and Vlek, C (2009) Encouraging pro-environmental behavior: An integrative review and research agenda, *Journal of Environmental Psychology*, 29, 307-317.

Thomson, C S, El-Haram, M, Egbu, C and Lou, E Exploring the potential of sustainability action plans within construction projects, *In*: *Proceedings of the 27th Annual ARCOM Conference*, Association of Researchers in Construction Management, Bristol, 5-7.

Tornatzky, L G and Klein, K J (1982) Innovation characteristics and innovation adoption-implementation: A meta-analysis of findings, *IEEE Transactions on Engineering Management*, (**1**), 28-45.

EQUALITY, DIVERSITY AND INCLUSIVENESS

AN ANALYSIS OF DIVERSITY MANAGEMENT IN THE CONSTRUCTION INDUSTRY: A CASE STUDY OF A MAIN CONTRACTOR

Julia Haizelden, Ramesh Marasini[1] and Emmanuel Daniel

Design and the Built Environment, Solent University, East Park Terrace, Southampton, SO140YN, UK

In recent times there has been increasing argument for diversity and inclusivity in work places. Although the construction industry is moving forward to improve diversity, there is still a long way to create a more inclusive workforce. Not only are there legal requirements that organisations must adhere to following the release of the Equality Act 2010, there is also a moral and business case for managing diversity. It has been speculated that improving diversity and reaching out to wider talent pools could help improve the skills shortage and poor productivity that is currently affecting the industry. However, there is limited evidence to substantiate this claim in the construction industry context. The aim of this study is to ascertain a theoretical perspective on how diversity management would improve the construction industry and evaluate whether a main contractor is managing diversity effectively. A theoretical framework was identified through the review of the literature to monitor the effectiveness of the DM strategies. A case study of a major contractor in the United Kingdom was carried out to see the extent to which the company is applying the diversity management requirements. The data were collected using document analysis, observations and three semi-structured interviews to understand their current approach to manage diversity. A questionnaire was also issued to all employees of the three southern region offices of the company to identify if the approach taken from senior management is working. The case study findings highlight that there are policies and tools in place to comply equality legislation and to improve and enhance diversity; the current practice within the case study organisation align with DM requirements identified in the literature. However, there is no coordinated effort to implement diversity management initiatives other than meeting legal requirements and this has not perused for the benefits such as improving productivity or fulfilling skills shortage. This study provides a new insight into how diversity could be managed in a construction organisation and contributes to future study of diversity management in general.

Keywords: diversity management, equality, women, ethnic minorities

INTRODUCTION

Diversity management (DM) is used by organisations to improve diversity by promoting and retaining a workforce from different backgrounds. This provides an inclusive environment for all employees to work together to meet organisational targets. It is a strategy used by organisations through a collection of ideas and procedures to recognise and value individuals from different backgrounds of its employees with benefits to be gained such as productivity and effectiveness (Kumra and Manfredi, 2012). Not only are there legal requirements that organisations must

[1] ramesh.marasini@solent.ac.uk

Haizelden, J, Marasini, R and Daniel, E (2019) An Analysis of Diversity Management in the Construction Industry: A case study of a main contractor *In:* Gorse, C and Neilson, C J (Eds) *Proceedings of the 35th Annual ARCOM Conference,* 2-4 September 2019, Leeds, UK, Association of Researchers in Construction Management, 465-474.

adhere to following the release of the Equality Act 2010, there is also a moral and business case for managing diversity. There are different aspects of diversity that have been studied by different researchers such as team diversity (Wu *et al.,* 2019; Horwitz and Horwitz 2007), this study focuses on the approaches taken by companies to manage diversity in the workplace in terms of composition of workforce mainly in terms of age, disability, gender and ethnicity.

It is argued that productivity is one area that diversity management could help improve. A more diverse workforce with less discrimination and employees feeling valued and respected team members in positive working environments results in stronger teams which leads to higher productivity (Equality and Human Rights Commission, 2011). There would be less absenteeism from discriminative behaviour and knowledge is retained with improved staff retention therefore performance will increase improving productivity. The construction industry is one of the largest sectors in the UK and a major contributor to the economy, however, the Office for National Statistics (2018) highlights that the construction industry is the least productive industry in the UK with more than 20 percentage points below the average output per hour for the whole economy.

Demographics in the labour market is also a key factor to improve diversity and the composition has become increasingly diverse therefore organisations need to attract new talent from the competition (Kirton and Greene, 2016). It has been speculated that improving diversity and reaching out to wider talent pools could help improve the skills shortage that is currently affecting the industry. According to CITB (2018), there is a huge skills shortage in the construction industry and there will be demand for more than 158000 jobs in next 5 years in the UK.

Although the construction industry is moving forward to improve diversity, there is still a long way to go to create a more inclusive workforce. Current statistics show that women only make up 14% of the construction industry (McGuinness, 2018), ethnic minorities as only 11.3% and less than 5% declared disability (Construction Industry Council, 2016) highlighting that improvements need to be made. Construction Industry Council (2016) also provide evidence suggesting women aged 25 and under make up 22% of the industry in that age bracket compared to women aged 46-55 making up only 4%. This highlights that more women are starting their careers in the construction industry however measures need to be put in place to retain older female construction employees.

There can also be cost implications for organisations if diversity is not effectively managed. An employee may decide to take an organisation to employment tribunal if they experience discrimination which could result in a high compensation payment. A key challenge with managing diversity is proving the effectiveness of the relationship between diversity and the benefits. There is a vast range of information confirming the positive benefits of diversity management however it is not easily supported with evidence. Capturing quantifiable benefits of equality and diversity for the business creates substantial methodological challenges (Government Equalities Office, 2013). There are also difficulties showing returns on investment when evaluating diversity (Kirton and Greene, 2016).

Although there are numerous benefits to a more diverse workforce for both the employees and the organisations, there is currently a gap on the current approach taken by construction companies towards improving diversity. Following the release of the Equality Act 2010, construction companies in the UK have a legal requirement

to comply with the regulations however there is no consistent framework used to implement and enhance diversity management. Different construction companies use their own methods for improving diversity therefore no consistent evidence is available regarding the effectiveness of their methods or what extent they are using it. Furthermore, it is not clear whether companies are using diversity management for legal reasons or there is a belief that the diverse workforce improves productivity and morale as well as helps to meet skills shortages and hence there is a business case for its management.

The aim of the study is to ascertain a theoretical framework that could be used to evaluate DM and its progress should be evaluated by the construction companies. Using a case study of a large main contractor in the UK, the study evaluates the extent to which the company has implemented diversity management and establishes whether the objectives of diversity management are achieved effectively. Finally, it argues that there is a need for further evidences to ascertain that DM increases productivity of the construction workforce.

Diversity Management and Evaluation Framework

Diversity Management needs to be an ongoing process, not a one-off initiative (CIPD, 2018) and would involve the creation of an equality policy. This is not a legal requirement however it would demonstrate that the organisation is a diverse employer fulfilling its moral and legal duties (CIPD, 2018). The first step for implementing diversity management into an organisation is to include diversity within the corporate strategy with support from leaders and senior management. Leadership need to enforce diversity to ensure it is implemented and passed down to all levels of the organisation. Cultural change is vital therefore leaders need to understand conceptually and practically culture change as it is key to the success or failure of Diversity Management (Arredondo, 1996).

There are not many frameworks available specifically for construction companies to use as guidance for improving diversity. One notable framework is Be FaIR framework created by the CITB that is tailored specifically for construction companies and is made up of 5 modules with supporting documents and templates (CITB, 2019). The modules covered include commitment, policies and procedures, employment, site environment and supply chain. The framework modules include free training and resources programme which covers leadership, recruitment, management, monitoring, training and procurement to help employers meet their legal obligations regarding equality (CITB, 2019). Companies can also get accreditation for enrolling in the Be FaIR framework which is valid for three years and provides ongoing support. As this framework is focussed on providing accreditation, this can be seen more about complying with the legal requirements instead of having a general framework that can support companies to monitor and evaluate their DM initiatives.

It is crucial to review and audit the diversity strategies to establish what is working and what needs improvement. This also allows the actions set within the strategy to be monitored and establish if the expected results have been met or if improvements need to be made (CIPD,2018). There are two main considerations for implementing diversity management; firstly, identification of policy requirements and secondly a method of measuring the effectiveness of the policy implementation. Through the literature review, it was identified that the policy requirements are comprehensively covered by the ACAS (ACAS, 2014) and the framework for measuring and monitoring the effectiveness of the policies are provided by the Royal Academy of

Engineering (RAE) through six Ps cultural analysis framework (RAE, 2015). Figure 2 shows the framework considered for the study of the diversity management by a case study company and evaluation of its effectiveness.

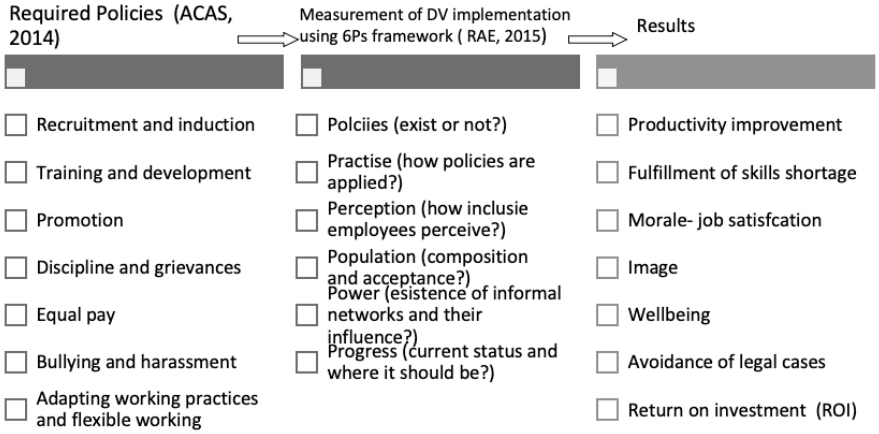


Figure 2: Diversity management requirements and measurement of its implementation and expected results

Description of the Six Ps Framework

This framework is called the six Ps cultural analysis framework (RAE, 2015) and covers six key areas that need review:

Policies - all policies require review in relation to employee life cycle such as flexible working, recruitment and selection, performance appraisal etc to ensure all policies are kept up to date with current legislation and follow best practise. These policies also need to be made available to the employees.

Practise - The day to day management practise must then be reviewed to establish how inclusive or flexible managers are or how policies and processes are applied. This will identify and address any areas of unconscious bias and develops a corporate culture putting diversity as a business requirement as opposed to an HR requirement.

Perception - The employee's perception should then be considered of how inclusive they view the organisations culture to identify areas that need improvement and can also relate to the policies and processes.

Population - The demographic composition of the organisation and its relation to key processes should be reviewed to identify if any opposing effect is occurring. This can be carried out through the use statistical information which can be used to set targets and measure progress.

Power - Consideration is needed regarding informal networks that may exist within the organisation and how much these networks impact career development, make people feel included/excluded or affect performance perceptions

Progress - Identify and understand where the company wants to be and where it currently stands with diversity. This also includes any progress that has already been made and it is a useful idea to look at benchmarks at this stage

Once information is gathered from the six Ps framework, it should be used to highlight the strengths and areas requiring development. The results will demonstrate how they are currently performing so can be compared to what they are trying to achieve. An action plan can then be put in place that identifies the key objectives,

which should be implemented within the organisation's strategy (RAE, 2015). Senior leaders should commit to the process and drive the initiatives within the organisation.

The benefits of DM in the literature highlighted productivity improvement, fulfilment of skill shortage, increased morale leading to job satisfaction, improved image of the company, wellbeing of the employee, avoidance of legal cases, and return on investment. These themes were used to evaluate whether the case study company achieved these benefits objectively or subjectively. Furthermore, the six Ps framework was used to evaluate the DM practice in the case study company.

RESEARCH METHOD

Data was collected using a case study of a major contractor in the United Kingdom to see the extent to which the company is applying the diversity management requirements. A case study selects one case, such as a construction company, and are investigated and analysed in a qualitative manner to achieve the research objective (Dul and Hak, 2007). Only one contractor was chosen for the case study to ensure a thorough analysis could be carried out on the implementation on DM. If additional contractors were analysed, it was felt the research findings may be lacking. The data was collected using semi-structured interviews with three senior managers mainly a Group Talent and Organisation Director, an Operations Director and a Project Manager to understand their current approach to managing diversity. The Group Talent and Organisation Director was chosen as they are responsible for the diversity and equality policy and strategy for the business and the interview lasted for approximately 22 minutes. The Operations Director was chosen to understand how they are implementing and driving diversity within the individual businesses with the interview lasting approximately 11 minutes. The Project Manager was chosen to recognise if the message of improving diversity has been communicated to employees involved in recruitment and selection and to gain their perspective on how their company are performing on improving diversity and the interview lasted approximately 10 minutes. A semi-structured interview was chosen as a list of questions were covered in the interviews; however, the interviewees responses can open up further lines of discussions which the interviewer can probe for further answers (Holland and Edwards, 2013). This method is appropriate for this study as the interviewee may also provide a considerably different response from the theoretical framework which allows the interviewer to pursue further questions to critically engage with the interviewee therefore providing further layers to the findings of the interview (Galletta, 2013). The interviews were recorded and transcribed to allow thematic analysis to be carried out. To collect the information about company policies and diversity data, document analysis and observations were used. To elicit the views of the employees, a questionnaire survey was electronically issued to 354 employees of all three southern offices of the case study company and 92 responses were received and analysed.

The framework identified through the literature review (Figure 2) was used to evaluate the effectiveness of diversity management by the case study company. The existence of policies and demographics data, initiatives used by the company etc. were elicited using the document analysis and views of management were collected using the semi-structured interviews, which covered practise, power and progress. Perception of employees was collected using the questionnaire survey.

CASE STUDY

Company A, which is one of the top 10 major construction contractors in the UK was used as a case study to study the status of the DM in construction in the UK. The company employs about 16000 people, out of which 77% are male and 23% female, as of 2018. Company A was selected because it is one of the UK major contractor which has claimed to have pursued diversity management initiatives.

The focus of the study is mainly on three offices, which represent Southern Region business of the Company A with £300 million turnover and more than 350 employees. They cover works in different sectors such as education, commercial offices, defence, health and civic buildings. The diversity management practices of the Southern region offices of the Company A were evaluated with the framework presented in Figure 2 following the 6Ps proposed by the RAE.

RESULT AND DISCUSSION

Evaluation of Policies Element

Document analysis of the case study organisation reveal that an Equality, Diversity and Inclusivity (ED&I) strategy has been created and implemented into the organisation which highlights the actions that will be taken towards leadership, the workforce and the workplace over 2019. Each office has 'Diversity Champions' to promote and raise awareness in each office of company A's commitment to improving diversity. This is achieved through regular communication about company initiatives and events relating to diversity, playing a Diversity board game with all employees to help improve diversity knowledge and having a diversity week. Company A are now corporate partner of the FIR (fairness, inclusion, respect) programme. The evaluation of policies required as per ACAS guidelines for the DM were present in the company as shown in Table 2.

Table 2: Presence of Diversity Policies

Policies	Present	Comments
Recruitment and induction	Yes	Part of Performance Development Review (PDR) discussions
Training and development	Yes	Training on unconscious bias
Promotion	Yes	-
Discipline and grievances	Yes	-
Equal Pay	Yes	Pay gap report published in 2017 and 2018
Bullying and harassment	Yes	-
Adapting working practices and flexible working	Yes	Agile working recently implemented

The above results show that company A has some policies in place which align with the RAE framework (RAE, 2015; ACAS, 2014). However, the drive for having this within the organisation is not obvious other than legal requirements.

Evaluation of the Practise Element

The interview result indicates that company A provides compulsory training to all employees about 'unconscious bias'. One of the respondents stated that 'the company use 12 to 18 months cycle in reviewing the policies however, if new legislation is released that impacts on the policy then the policy would instantly be reviewed and updated'[Interviewee one, The Talent and Organisation Director]. The survey results show that 32.61% of employees involved in the recruitment and selection process

have received training to ensure fairness and to avoid bias whereas 8.7% confirmed they have not received training. 23.91% of managers who carry out PDR's have received training on how to ensure fairness with progression and promotion whereas 11.96% confirm they have not received training. Although these percentages show that more employees or managers have received training than not, there is still a need to ensure that training is provided to all relevant employees. It could be argued that creating diversity awareness through training may not necessary lead to effective result. According to Sanchez *et al.,* 2004 creating diversity awareness in an organisation without supportive work environment would not produce good outcome.

Employees were asked whether they were aware of their company's equality and diversity policy to see if the policy had been communicated effectively to the employees. A majority of 80.43% confirmed that they are aware and 13.04% confirmed as being 'very aware' of the policy. Only 6.52% were unaware/very unaware of the policy which highlights that the company has effectively communicated their policy to its employees. Although, majority of the respondents claim to be aware of the policy and believe that the diverse workforce will improve productivity and help solve skills shortage. One of the survey respondents suggested the areas of improvements as 'make the board / senior levels reflect the communities in which we live. Increase women in senior positions and make people constantly aware of the unconscious bias that we all have' which suggests there is more to be done to achieve the diverse workforce within the company A. This shows DM practice should go beyond awareness to holistic implementation.

Evaluation of the Perception Element

Table 3 shows the survey responses of the employee of the case study company, which shows that there is a general agreement in the benefits of the DM.

Table 3: Cast study company employees view on DM

Statements	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Response Total
A diverse workforce is important for the future performance of the construction industry	2.2% (2)	1.1% (1)	20.7% (19)	47.8% (44)	28.3% (26)	92
A diverse workforce will help improve productivity	2.2% (2)	4.3% (4)	40.2% (37)	34.8% (32)	18.5% (17)	92
A diverse workforce will help improve the current skills shortage	1.1% (1)	5.4% (5)	31.5% (29)	35.9% (33)	26.1% (24)	92
It is important to improve equality and diversity in construction	0.0% (0)	3.3% (3)	13.0% (12)	50.0% (46)	33.7% (31)	92
A company showing commitment to diversity makes them a preferable employer	1.1% (1)	2.2% (2)	18.5% (17)	51.1% (47)	27.2% (25)	92

Employees were asked whether they feel the current actions taken by the company to improve diversity and the responses highlighted 'mostly average' (44.57%) and with 'good action' taken (40.22%), which shows that employees feel the company is trying to improve diversity however improvements need to be made to show employees that they are doing more. Ten respondents felt that minimal or no action has been taken

which does not seem to correlate with the high awareness of the company's equality and diversity policy and its numerous initiatives.

One of the respondents of the survey highlighted 'the company needs to educate all employees, managers etc. on how to stop stereotyping a person, and what the implications of doing so can have on themselves, the company and the person they are stereotyping'. According to Munns, 1996 stereotyping leads to poor communication and conflict on construction project. The respondent also stated that 'the online training which is currently used I do not feel is adequate'. Other respondent highlighted 'more training and sensitivity training with people not computer based. We still have a large "old days" culture that don't see the problem with the way they use language as it always used to be ok. But the training currently provided is computed based, which I don't find enables you to genuinely understand why these things aren't ok anymore.'

The Project Manager (Interviewee 3) highlighted that there is focus on the DM as a strategic objective however, the interviewee felt that the activities have been mostly tick box exercise and suggested that there needs to be a cultural change saying " bring people through, motivating, mixing teams up from different backgrounds, different age, different sexes, I think they could do more". They also felt that leadership were not effectively driving diversity within the business although believing they do want to drive it but need to change the barrier of their middle age mindset.

Evaluation of the Population Element

The 2019 diversity report for the three offices for southern region of Company A shows that only 2.54% of employees consider themselves as BAME with no BAME employees in the most southerly office. There is 1 LGBT person in each office and only 2 employees who consider themselves disabled. Unfortunately, data was not obtainable for previous years so the percentage of women at 21.47% cannot be compared to show if this has increased or decreased. The age range shows that most women are aged 25-34 with only 7 women at a younger age of 16-24 compared to 24 males. There has been no increase in BAME employees over the last three years and female graduates are reducing. In 2016, the company had a set up objectives of 70:30 gender split for recruitment by 2020, however, this has not been achieved yet. This suggests that although some targets have been set, there is no concentrated effort in recruitment to achieve a diverse workforce.

Evaluation of the Power Element

The company has used several networks such as LGBT+ network and BAME (black, Asian and minority ethnic) action group. There is no evidence to suggest that the company actively seeks to establish whether any informal networks that may exist within the organisation and their impact in career development, inclusivity or performance perceptions. Interviewee 2 who is the Operations Director for one of the businesses did not feel there was anyone overtly bigoted within the business and felt that everyone was reasonably open.

Evaluation of the Progress Element

Interviewee 2 highlighted that 'the company provides the online training that's structured and we mandate to make sure everyone in the business at least looks at them and goes through the training because it's about that awareness part of the business. However, there is a lack of evidence of where the company wants to be. Although company A are monitoring the metrics of the number of women, BAME etc. within the business, there seems to be no process in place made by the company to

monitor the effectiveness of the initiatives and link to the benefits that company may realise (improved productivity, fulfilment of skills shortage etc as shown in Figure 2). This lack of understanding to the benefits of DM is reflected in the questionnaire results which showed 40% of employees rated neutral when asked if a diverse workforce would improve productivity and 31% rated neutral when asked if a diverse workforce would help the current skills shortage affecting the industry. Company A need to communicate the benefits of improving diversity within the organisation to educate and change the perceptions of its employees towards diversity. However, DM has only been applied quite recently within Company A with interviewee 1 being quite honest that over the last three years they have started from a relatively low basis and have made progress on improving diversity but still have lots more to do to improve diversity.

CONCLUSIONS

The aim of the current study is to ascertain a theoretical framework that could be used to evaluate DM and to evaluate how DM practice in a construction company align with identified framework. The study found that there is no unified framework for managing diversity. However, the framework for measuring and monitoring diversity provided by the Royal Academy of Engineering (RAE) seems to be very developed.

The study found that some of the current practice within the case study organisation align with the some of the practice stipulated in the RAE framework for managing diversity and there is no coordinated effort to implement diversity management initiatives other than meeting legal requirements and this has not pursued for the benefits such as improving productivity a or fulfilling skills shortage. This is not evidenced by their recruitment policy. Although respondents and interviewee agree that there will be productivity improvement as a result of DM in principle, but no effort has been made to measure it.

The investigation revealed that the corporate action plan is not being driven successfully by the senior leaders within the individual businesses and there is a lack of clear vision and framework to monitor the progress on the implementation of diversity management initiatives. The current approach is seen as tick box exercise. Although it is not possible to generalise the findings, which of course is not the purpose of the study, the current study provides a new insight into how diversity could be managed in a construction organisation and contributes to future study of diversity management.

REFERENCES

ACAS (2014) *Delivering Equality and Diversity Booklet.* Available from https://skillmakers.co.uk/library/downloads/Acas_Delivering_Equality_and_Diversity_Nov_11-accessible-version-Apr-2012.pdf [Accessed 18 Nov 2018].

Arredondo, P (1996) *Successful Diversity Management Initiatives: A Blueprint for Planning and Implementation.* London: Sage Publications.

CIPD (2018) *Diversity and Inclusion at Work - Facing Up to the Business Case.* Available from https://www.cipd.co.uk/Images/diversity-and-inclusion-at-work_2018-facing-up-to-the-business-case-technical-report_tcm18-47062.pdf [Accessed 20 Nov 2018].

CITB (2019) *What is the Be Fair Framework*? Available from https://www.citb.co.uk/standards-and-delivering-training/be-fair-framework/what-is-the-be-fair-framework/ [Accessed 21 Mar 2019].

Construction Industry Council (2016) *A Blueprint for Change - Measuring Success and Sharing Good Practice.* Diversity and Inclusion Panel. Available from http://cic.org.uk/networks-and-committees/diversity-panel.php [Accessed 24 Oct 2018].

Dul, J and Hak, T (2007) *Case Study Methodology in Business Research*. Abingdon: Routledge.

Equality Act (2010) Available from https://www.gov.uk/guidance/equality-act-2010-guidance [Accessed 18 Nov 2018].

Equality and Human Rights Commission (2011) *Equality and Diversity: Good Practice for the Construction Sector.* Available from https://www.equalityhumanrights.com/sites/default/files/ed_report_construction_sector.pdf [Accessed 24 Oct 2018].

Government Equalities office (2013) *The Business Case for Equality and Diversity: A Survey of the Academic Literature. London, UK:* Department for Business Innovation and Skills.

Gillham, B (2007) *Developing a Questionnaire 2nd Edition*. London: Continuum International Publishing Group.

Holland, J and Edwards, R (2013) *What is Qualitative Interviewing*? London: Bloomsbury Publishing.

Horwitz, S and Horwitz, I (2007) *The effects of team diversity on team outcomes: A meta-analytic review of team demography, Journal of Management*, 33(**6**), 993.

Kumra, S and Manfredi, S (2012) *Managing Equality and Diversity.* Oxford: Oxford University Press.

McGuinness, F (2018) *Women and the Economy,* HM Government, House of Commons Library Briefing Paper.

Munns, A K (1996) Measuring mutual confidence in UK construction projects, *ASCE Journal of Management in Engineering*, 12(**1**), 26-33.

Office for National Statistics (2018) *Construction Statistics.* Available from https://www.ons.gov.uk/businessindustryandtrade/constructionindustry/articles/constructionstatistics/number192018edition [Accessed 24 Oct 2018].

Royal Academy of Engineering (RAE) (2015) *Increasing Diversity and Inclusion in Engineering - a Case Study Toolkit.* Available from https://www.raeng.org.uk/publications/reports/increasing-diversity-and-inclusion-in-engineering [Accessed 10 Jan 2019].

Sanchez, J I and Medkik, N (2004) The effects of diversity awareness training on differential treatment, *Group and Organization Management*, 29(**4**), 517-536.

Wu, G, Zhao, X, Zuo, J and Zillante, G (2019) Effects of team diversity on project performance in construction projects, *Engineering, Construction and Architectural Management*, 26(**3**), 408-423.

FINANCIAL MANAGMENT

FINANCIAL MANAGEMENT STRATEGIES THAT INFLUENCE PROJECT AND ORGANISATION PERFORMANCE

Emmanuel Dele Omopariola[1] and Abimbola Windapo

Construction Economics and Management, University of Cape Town, Rondebosch, Cape Town, South Africa

The study examines the financial management strategies used by construction organisations and whether these approaches result in competitive advantages, and improved project and organisational performance. The grounds for the examination stem from arguments held by scholars that the type of financial management strategy used by organisations on construction projects affects performance and corporate sustainability. Also, there is limited research that explores how financial management strategies influence project and organisation performance. The study employs a systematic review of extant literature and employs a quantitative research approach. A questionnaire survey of construction companies listed in Grade 7 to 9 on the Construction Industry Development Board (CIDB) Register of Contractors was conducted to obtain information required to address the research objective. Using this approach, the study first of all developed a conceptual framework that linked the financial management strategies used by construction organisations on their construction projects, and the organisational performance of those construction organisations, from a systematic literature review. Thereafter, the data collected was analysed using the mean score, regression analysis, and Z-test. It emerged from the study that cash flow, leverage and liquidity are effective performance evaluation systems for the construction project and organisations in South Africa. It was also found out that budgeting, creditworthiness, risk management, review and evaluation are effective financial management strategies among the organisations surveyed; and that the financial management strategies used have a positive effect on project and organization performance. Therefore, the study concludes that construction organisations will perform better when a combination of financial management strategies are used in their operations. However, further studies using empirical validation are required to determine which of the financial management strategies in the construction industry best fits the need for construction businesses to deliver successful construction projects and improved organisational performance.

Keywords: budgeting strategy, creditworthiness, evaluation, risk management

INTRODUCTION

Globally, the construction industry comprises three distinct features (size and nature of its products - large and site produced by a craft-based workforce and dependent on local conditions; each project takes a relatively long time to produce and differs in size, shape and aesthetics; and demand for its products is mainly for investment of goods) that differentiates it from all other sectors of a nation's economy (Adeyemi,

[1] ompemm002@myuct.ac.za

Omopariola, E D and Windapo, A (2019) Financial Management Strategies That Influence Project and Organisation Performance *In:* Gorse, C and Neilson, C J (Eds) *Proceedings of the 35th Annual ARCOM Conference,* 2-4 September 2019, Leeds, UK, Association of Researchers in Construction Management, 476-485.

2004; Obiyan, 1989). Hillebrandt (1985) observes that the industry is vast, although exceptionally disjointed, varied and dispersed, with a predominance of small firms, a few medium-sized firms and a minimal number of large firms. The explanation for the range of companies in the industry is that it is easier to cross the threshold required to establish a construction enterprise by all types of entrepreneurs who are not proficient in the management of resources, have the technical know-how and financial means to manage a successful construction company (Windapo and Cattell, 2011; Obiyan, 1989); a situation that could lead to project failure and ultimately construction company insolvency.

Haupt and Padayachee (2016) posit that sound application of financial management strategy contributes to successful construction businesses. Oke *et al.,* (2016) posit that the accomplishment of any construction project relies significantly on the level of (financial) resources, organizational performance, and appropriate financial management strategies, the completion time set for the project and the managerial input of the relevant players involved. An adequate financial management strategy has been recognised as a critical success factor for any construction company for efficient delivery of the construction project (Singh and Lakanathan, 1992).

Strategy, in effect, is management's game plan for consolidating and strengthening the construction organisation's setting, satisfying customers, and attaining performance targets (Festus and Adeniran, 2013). In the contemporary economic market, a good strategy helps increase the competitiveness of construction businesses, guaranteeing a strong dominance of the enterprise (Nguyen, 2018). Strategy has been used to varying degrees in the construction industry as a tool for financial management and decision making (Odeyinka *et al.,* 2003; RICS, 2014). Bell (2003) describes financial management strategy as the capability of corporate organisations to develop from having the ability, to a level of gaining financial competence that may help them deliver their optimum performance.

Consequently, to inspire performance in construction projects requires effective and sound financial management approaches (Arditi *et al.,* 2000; Bell, 2003). The failure of construction projects and their association with financial hitches has thus placed financial management in the lead of many construction activity/business requirements (Mutti and Hughes, 2002). This has emphasised the importance of financial management strategies and management that has given rise to the development of numerous financial models for projects. Nevertheless, most of the current models are either project specific or do not discuss the significance of good financial management and its impact on the project and organisational performance, within the construction company. More also, as construction project activities become more complex, the construction organisation requires a better set of strategies to deal efficiently with the risks and challenges that face their operation.

This study examines the influence of financial management strategies - budgeting strategy, cash flow forecast/projection strategy, creditworthiness strategy, review and evaluation strategy, and risk management strategy on project and organisation performance. To do this, the paper first presents a systematic literature review of financial management strategies and its effects on project and organisation performance. After that, it outlines the research methodology used, it proposes a framework to understand the influence of financial management strategies on project and organisational performance, and validates the framework using empirical data. Finally, it presents the study findings and conclusion.

Effects of Financial Management Strategies on Project and Organisation Performance

Calvert *et al.,* (2003), Wang *et al.,* (2015), Haupt and Padayachee (2016) identified different types of financial management strategies (FMS) currently in use regarding the achievement of construction project and organisation performance namely: Cash flow forecast/projection strategy, budgeting strategy, creditworthiness strategy, risk management strategy, review and evaluation strategy.

Cash flow forecast refers to knowledge about the rates and fees, which affect expenses and revenue, together with their combined effect on the construction project cash balance. It serves as a cost-controlling tool during construction work stage (Hwee and Tiong, 2002). Budget is a control mechanism for construction organisation liquidity or availability of adequate cash. Creditworthiness as financial management strategy represents the inherent value of firms and construction businesses mirrored in their capability and willingness to realise their business objectives (Safi and Lin, 2014). Chang and Zwei, (2011) established that the risk management strategy reduces the chances of negative impacts on construction company business operations and performance. As a function of risk management, the positive effect of leverage on construction organisation value tends to be stronger when the financial quality of the construction company is better. Alfan and Zacharia (2013) concluded that review and evaluation strategy would help the construction organisations eliminate any inconsistencies happening in the future, based on their insight into their past financial performance, and therefore ensuring the achievement of the best value for the firm, by formulating a series of new strategies.

Performance of organizations and projects demonstrates an outcome which rests upon efficient construction plans that are carried out within completion time, within budget and to the required level of quality (Owolabi *et al.,* 2014); the measurement of a construction component, stakeholders, an organization and realization of the work outline; profitability, liquidity, productivity, sufficient cash flow, leverages, market share, order value, and meeting customer and employee satisfaction (Allen and Helm, 2006, Tucker *et al.,* 2015); and indicating the capacity of the technical expertise of an organization (Hatush and Skitmore, 1997).

Previous research by Odeyinka *et al.,* (2003) and Windapo and Cattell (2011) confirmed that the financial management strategies employed by a company impact on the project and company performance. Arditi *et al.,* (2000), and Wang *et al.,* (2015) posit that getting acquainted with financial management strategies (such as cash flow, appropriate debt management strategies which helps to develop the creditworthiness of companies, risk management, budgetary plan, review and evaluation), aids the decision-making process. According to Sheriff and Kaka (2003) the successful completion of a construction project hinges on the appropriateness of the financial management strategies aligned to the project features and constraints. Consequently, financial management strategies are the sine qua non to construction company and project performance.

Developing a Framework for the Relationship Between Financial Management Strategies (FMS) and Project and Organization Performance (P&OP)

Resource-based theory is adopted in this study. Resource-based theory submits that company resources and competencies impact on the growth and performance of the company (Mahoney and Pandian, 1992). Resources can be categorized as financial, physical, social, scientific, and organization (Grant, 1991). Barney (1991) posits that

the major impression about the resource-based view is that when the company makes use of better strategies such company will attain a sustainable competitive advantage and ultimate superior growth and performance if the company facilitates and relates them well. Wang *et al.,* (2015) postulate that getting acquainted with financial management strategies (such as payment of bills on time to the supply chain, appropriate debt management which helps develop the creditworthiness of companies and sustain company performance), will aid the decision-making process. The company in this study is described as a set of dynamic resources (financial) and administrative organisation.

As presented in Figure 1, five financial management strategies and six projects and organisation performance measures were identified from the literature. Figure 1 conceptualised a framework linking the FMS used by construction organisations to the six Projects and Organisation Performance (POP). The framework relationships show the influence of FMS on POP. First, the cash flow strategy has an impact on profitability, sufficient cash flow, and liquidity. This relationship is supported by Calvert *et al.,* (2003) and Melita (2019) who highlighted that the progress of any construction project depends mainly on sufficient cash flow and profitability. Also, Navon (1996) concluded that liquidity and sufficient cash flow are affected by cash flow strategies. A similar study by Mohammed *et al.,* (2014) validate this relationship.

The second relationship in Figure 1 links the budgetary strategy, profitability, sufficient cash flow, and liquidity. The investigation by Sur and Chakraborty (2011) provides support for this relationship. The budget represents a company's liquidity, evidence of sufficient cash, and a tool for making a profit (Defranco,1997). Therefore, any budgetary interests will influence the degree of liquidity, sufficient cash flow, and profitability of a project or an organisation (Harelimana, 2017). The third relationship identified in Figure 1 is the relationship between creditworthiness strategy, sufficient cash flow and leverage. Studies have shown that most construction organisations are not creditworthy because of inflation, interest rates, and insufficient cash flow (see Kangari, 1991; Berger and Frame, 2007). This confirms that the selection of creditworthiness strategy by construction organisations depend on its impact on leverage and sufficient cash flow (Visconti, 2013). The other relationships identified in Figure 1 are the impact of risk management on leverage, order value, and market share; and the impact of review and evaluation strategy on profitability, sufficient cash flow, and liquidity. Studies by Alfan and Zacharia (2013), Panayiotis (2018) and Sugiharto *et al.,* (2016) provide support for these relationships.

RESEARCH METHODS

The study formulated a framework illustrating the relationship between FMS and POP based on literature review in Figure 1. The effect and relationship between FMS and POP were evaluated using a structured questionnaire. The questionnaire was designed to elicit information such as level of FMS and POP in use from the respondents using a five-point Likert scale (where 1=very low and 5= very high). The choice of questionnaire survey in the study was informed by the need to explain the application of the resource-based theory in the context of financial management strategies used by a wide variety of construction organisations.

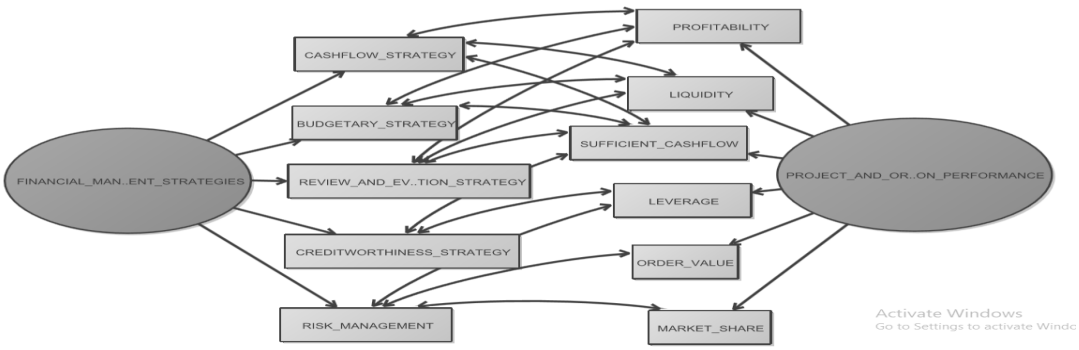


Figure 1: Framework of relationships between Financial Management Strategies (FMS) and Construction Project and Organization Performance (POP).

The study employs SurveyMonkey web-based platform in questionnaire administration. The ethical considerations in the study include keeping the respondents anonymous and reporting the responses in an aggregated format. The population for this study includes all 504 contractors listed in Grade 7 to 9 on the cidb Register of Contractors in South Africa. The survey was sent to 50% of the population equating to a sample size of 252. As at April 24, 2019, 47 responses were received, which implies a response rate of 18.65%.

The data collected from the respondents were analysed using Mean score, Regression analysis, and Z-test. Mean score was used to identify the common FMS and POP among respondents. Regression analysis was employed to test the effect of FMS on POP; While Z-test was conducted to validate the relationship between FMS and POP. The Cronbach alpha test for data reliability was used in confirming if the responses obtained were reliable. The Cronbach's coefficient obtained for this survey was 0.81, which indicated that the responses were reliable (Hair at al., 1998). The limitation of the study is that it is a preliminary study from an on-going PhD research. This will have an implication on the findings and conclusions of the study.

RESULTS AND DISCUSSION

Effects of Financial Management Strategies (FMS) on Project and Organization Performance (POP)

The responses of 47 respondents from an ongoing PhD research work was used to validate the relationship identified in the framework. The analysis of the respondents' profile shows that 53.19% of the respondents have a bachelor's degree, 25.53% have a Higher diploma, 12.77% have a Certificate, and 8.51% have N4-6/NTC certificate. For the designation of respondents, 70.21% of the respondents are in the Director cadre, 25.53% are in the Management cadre, and 6.38% indicated other designation. Only 29.05% of the respondents are Grade 7 contractors, 25.23% are Grade 8 contractors; while the majority of the respondents (45.72%) are Grade 9 contractors. For the class of work, 47.57 of the respondents are general building contractors, 47.43% of the respondents are civil engineering contractors; while 5.00% of the respondents are both general building and civil engineering contractors. The results show that information from the respondents will be reliable and unbiased owing to their educational qualifications and level of experience.

Firstly, the study sought to know the respondents' level of usage of the identified FMS and the level of POP. Data collected regarding this enquiry is presented in Tables 1 and 2. Table 1 shows that only sufficient cash flow (MS=4.09) has a high level of usage, while Leverage (MS=3.45) and Liquidity (MS=3.66) have an average level of

usage among the respondents. Profitability (MS=2.94), Order value (MS=2.83) and Market share (MS=2.32) are scored low among the respondents.

The results suggest that most of the respondents make use of sufficient cash flow, leverage, and liquidity as evaluation strategies for POP. Among the FMS presented for the respondents, only cash flow forecast has a low level of usage among the respondents (Table 2). Table 2 also shows that majority of the respondents employ budgeting (MS=3.89), creditworthiness (MS=3.32), risk management (MS=3.44), and review and evaluation (MS=3.52) as strategies for Financial management. The findings suggest that budgeting creditworthiness, risk management, and review and evaluation are common strategies that are being used as FMS. These findings corroborate the study by Haupt and Padayachee (2016) who identified these strategies as the common FMS.

Regression analysis was conducted to estimate the strength of the effect that FMS has on POP. The coefficient of determination (R^2 =0.408) indicates that FMS used by the respondents explains 40% of the POP. The result suggests that FMS explains a low proportion of variability in POP. The correlation coefficient (r=0.811) indicates that FMS is positively correlated with POP. This suggests that the strength of the relationship between FMS and POP is such that as the FMS increases, the POP also tends to increase. The effect of FMS on POP is not statistically significant because the P-Value (0.24) is greater than the significance level of 0.005. Thus, suggesting that there is insufficient evidence to conclude that FMS influences POP.

Table 1: Means score of Project and Organisation Performance Evaluation Strategies

Project and Organisation Performance	Mean Score	Population mean	Variance	Standard deviation
Profitability	2.94	3.394	0.270	0.520
Sufficient Cashflow	4.09			
Liquidity	3.66			
Leverage	3.45			
Order value	2.83			
Market Share	2.32			

Table 2: Means Score of Financial Management Strategy

Financial Management Strategy	Mean Score	Population mean	Variance	Standard deviation
Budgeting	3.89	3.37	0.168	0.409
Review and evaluation	3.52			
Risk management	3.44			
Creditworthiness	3.32			
Cashflow forecast/Projection	2.75			

Validation of the Relationship Between Financial Management Strategies (FMS) and Project and Organization Performance (P&OP)

Z-test was conducted to compare the means and validate the relationships between FMS and POP. Eleven relationships were identified between FMS and POP (see Figure 1). The results in Table 3 show Z-test values for these relationships. Out of eleven relationships, only four relationships are statistically significant. These

relationships are cashflow forecast and liquidity (P=0.002), cash flow forecast and sufficient cash flow (P=0.000), review and evaluation strategy and sufficient cash flow (P=0.042) and creditworthiness and sufficient cash flow (P=0.009). These significant relationships are illustrated in Figure 2. The findings imply that the cash flow forecast strategy determines the liquidity and cash sufficiency of construction projects and organisations. Similarly, creditworthiness, review and evaluation strategies, influence the cash sufficiency of construction projects and organisations.

Table 3: Z-test of the relationships between FMS and ORP

Relationships	Mean difference	Z-test	P-value
CAS↔PRO	0.19	-0.574	0.282
CAS↔LIQ	0.19	-2.750	0.002
CAS↔SUC	1.34	-4.049	0.000
BUD↔PRO	0.95	0.003	0.500
BUD↔LIQ	0.23	0.004	0.500
BUD↔SUC	0.20	-0.604	0.272
REV↔PRO	0.58	0.006	0.500
REV↔LIQ	0.14	-0.423	0.336
REV↔SUC	0.57	-1.722	0.042
CRE↔SUC	0.77	-0.002	0.009
CRE↔LEV	0.13	-0.039	0.347
RIS ↔ LEV	0.01	-0.030	0.487
RIS↔ORD	0.61	-0.001	0.500
RIS↔MAR	1.12	0.000	0.500

CAS=Cashflow forecasting/projection strategy; PRO=Profitability; LIQ=Liquidity; SUC=Sufficient cashflow; BUD=Budgeting strategy; REV=Review and evaluation strategy; CRE= Creditworthiness strategy; LEV= Leverage; RIS=Risk management strategy; ORD= Order value; MAR= Market share.

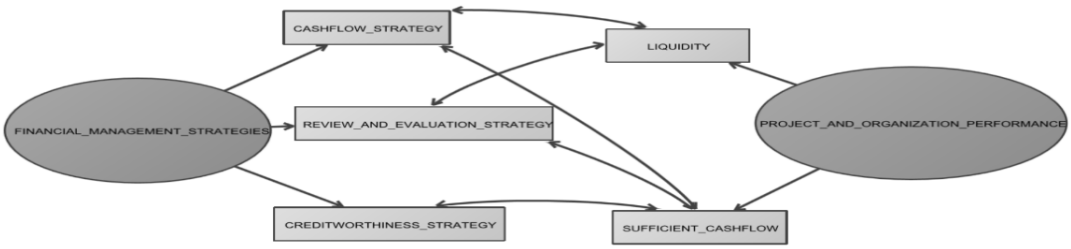


Figure 2: The Valid Relationships between Financial Management Strategies and Project and Organisation Performance

FINDINGS, CONCLUSION AND FURTHER RESEARCH

The influence of the financial management strategies - cash flow forecast/projection, budgeting, creditworthiness, risk management and review and evaluation, on the various types of project and construction performance is illustrated in Figure 1 using the categories of each type of financial management strategy. Six types of construction project and organisation performance were identified, namely profitability, liquidity, sufficient cash flow, leverage, order value and market share of the construction company. The validation of the identified relationships using

regression analysis and z-test indicate that only the relations between cashflow forecast strategy and liquidity, cashflow forecast strategy and sufficient cash flow, review and evaluation and liquidity, review and evaluation strategy and sufficient cash flow, and creditworthiness strategy and sufficient cash flow are valid. The valid relationships were illustrated in Figure 2.

The study also confirmed that sufficient cash flow, leverage, and liquidity are effective performance evaluation systems for projects and organisations in South Africa. Financial management strategies were found to have a positive effect on project and organisation performance. Lastly, budgeting, creditworthiness, risk management, and review and evaluation were found to be effective financial management strategies among the organisations sampled.

Based on these findings, the study concludes that success in today's competitive settings necessitates that a construction organisation employs budgeting, creditworthiness, review and evaluation, and risk management strategies in line with their growth plan, goal attainment and resource deployment. For example, if a construction organisation employs either budgeting strategy, risk management strategy, creditworthiness strategy or review and evaluation strategy to manage its finance, it would result in better performance in the area of sufficiency of cash flow, liquidity and leverage in the organisations and on construction project performance. The study recommends that further studies using empirical validation should be undertaken to determine which of the FMS in the construction industry best fits the need for construction businesses to deliver successful construction projects and improved organisational performance. Also, the interrelationships between the FMS and POP must further be investigated.

ACKNOWLEDGEMENTS

The financial support of the University of Cape Town (UCT), the National Research Foundation (NRF) and TETFUND regarding this study are hereby acknowledged. The concepts articulated, and inferences arrived at, are those of the authors and are not really to be attributed to UCT, NRF or TETFUND.

REFERENCES

Adeyemi, A Y (2004) *An Evaluation of Financial Performance of Construction Contractors in Nigeria*. PhD Thesis, Obafemi Awolowo University, Ile-Ife, Nigeria.

Alfan, E and Zacharia, Z (2013) Review of financial performance and distress: A case of Malaysian construction companies, *British Journal of Arts and Social Sciences*, 12(**11**), 1-15.

Allen, R S and Helms, M M (2006) Linking strategic practices and organizational performance to Porter's generic strategies, *Business Process Management Journal*, 12(**4**), 433-454.

Arditi, D Koksal, A and Kale, S (2000) Business failures in the Construction Industry Journal of Engineering, *Construction and Architectural Management*, 7(**2**), 120-132.

Barney, J B (1991) Firm resources and sustained competitive advantage, *Journal of Management*, 17(**1**), 99-120.

Bell, M (2003) *Knowledge Resources, Innovation Capabilities and Sustained Competitiveness in Thailand*, Final report to NSTDA, SPRU, Brighton.

Berger, A N and Frame W S (2007) Small business credit scoring and credit availability, *Journal of Small Business Management*, 45(**1**), 5-22.

Calvert, R E Bailey, G and Coles, D (2003) I*ntroduction of Building Management 6th Edition*. London: Butterworth Heinemann Publications.

Chang, M and Zwei, C T (2011) The effect of leverage on firm value and how the firm financial quality influence this effect, *World Journal of Management*, 3(**2**), 30-53.

Defranco, A (1997) The importance of financial forecasting and budgeting at the departmental level in the hotel industry as perceived by hotel controllers, *Hospitality Research Journal*, 20(**1**), 99-110.

Festus, A F Adeniran, F S (2013) Strategic planning and performance: Catalyst for sustainability and stability in the Nigerian financial sector, *European Scientific Journal,* 9(**25**), 318-334.

Grant, R B (1991) A resource base theory of competitive advantage: Implications for strategy formulation, *California Management Review*, 33(**3**),114-135.

Hair, J F Anderson, R E Tatham, R L and Black, W C (Eds.) (1998) *Multivariate Data Analysis*. New Jersey: Prentice-Hall International.

Harelimana, J B (2017) The effect of budgetary control on financial performance of Kigali Serena Hotel in Rwanda, *Business Economic Journal*, 8(**1**), 292-303.

Hatush, Z and Skitmore, M (1997) Criteria for contractor selection, *Construction Management and Economics*,15(**1**), 327-340.

Haupt, T C and Padayachee, K (2016) Financial Management capacity and business failure of contractors, *In*: *10th Building ASOCSA Environment Conference*, 31 July-2 August 2016, Porth Elizabeth, South Africa, 213-226.

Hillebrandt, P M (1985) *Economic Theory and the Construction Industry 2nd Edition*. London: Macmillan.

Hwee, N G and Tiong, R.L.K (2002) Model on cash flow forecasting and risk analysis for contracting firms, *International Journal of Project Management*, 20(**1**), 351-363.

Kangari, R (Ed.) (1991) Construction business failure and risk management in the USA, *In: Management, Quality and Economics in Building*, London: Spoon.

Mahoney, J T and Pandian, J R (1992) The resource-based view within the conversation of strategic management, *Strategic Management Journal*, 13(**5**), 363-380.

Melita, C (2019) Which profitability measures explain better the bank's financial soundness? *Journal of Finance and Economics*, 7(**2**), 62-67.

Mohammed, A, Ali, A and Sumaiya, A T (2014) Contractual implications of cash flow on owner and contractor in villa construction project, *International Journal of Research in Engineering and Technology*, 3(**4**), 442-447.

Mutti, C d N and Hughes, W (2002) Cash flow management in construction firms. *In:* Greenwood, D (Ed.), *Proceedings of the 18th Annual ARCOM Conference*, 2-4 September 2002, Northumbria, UK. Association of Researchers in Construction Management, Vol. 1, 23-32.

Navon, R (1996) Company-level cash flow management, *Journal of Construction Engineering and Management*, 1(**1**), 22-29.

Nguyen, X D (2018) Strategy for business development of Agricbank Thanh Hoa to 2020, *International Journal of Econometrics and Financial Management*, 6(**2**), 27-35.

Obiyan, T U (1989) Constraints of construction industry in Nigeria - A challenge for solution, *Journal of the Federation of Building and Civil Engineering Contractors in Nigeria* 6(**2**), 35-37.

Odeyinka, H A, Kaka, A and Marledge, R (2003) An evaluation of construction cash flow management approaches in contracting organizations. *In:* Greenwood, D J (Ed.), *Proceedings 19th Annual ARCOM Conference*, 3-5 September 2003, Brighton, UK. Association of Researchers in Construction Management, Vol. 1, 33-41.

Oke, A Ogungbile, A Oyewobi, L and Tengan, C (2016) Economic development as a function of construction project performance, *Journal of Construction Project Management and Innovation*, 6(**2**), 1447-1459.

Owolabi, A O Chan, A A and Ogunlana, A A (2014) Roots Causes of construction project delays in Singapore, *Journal of Construction Management*, 4(**1**), 19-31.

Panayiotis, G A (2018) Liquidity as an asset pricing factor in the UK, *Journal of Financial Management, Markets and Institutions*, 6(**2**), 1-24.

RICS (2014) *Quantity Surveying and Construction Standards: Cash Flow Forecasting*. http://www.isurv.com/site/scripts/documents.aspx [Accessed 12/01/2019].

Safi, R and Lin, Z (2014) Using non-financial data to assess the creditworthiness of businesses in online trade, *In*: *PACIS 2014 Proceedings*, 206(**1**), 1-14.

Sherif, E and Kaka, A (2003) Factors influencing the selection of payment systems in construction projects. *In:* Greenwood, D J (Ed.), *Proceedings 19th Annual ARCOM Conference*, 3-5 September 2003, Brighton, UK. Association of Researchers in Construction Management, Vol. 1, 63-70.

Singh, S and Lakanathan, G (1992) Computer-based cash flow model, *In*: *Proceedings of the 36th Annual Transactions of the American Association of Cost Engineers - AACE, AACE*, WV, USA, 5(**1**) 5-14.

Sugiharto, H J Tri, R and Srie, H M (2016) Risk management mediates the influence of good corporate governance, managerial shareholder and leverage of firm value, *Journal of Business and Management*, 18(**11**), 62-70.

Sur, D and Chakraborty, K (2011) Evaluating relationship of working capital and profitability: A study of select multinational companies in the Indian pharmaceutical sector, *The Journal of Management Research*, 10(**2**), 11-23.

Tucker, G C Windapo, A and Cattel, K (2015) Exploring the use of financial capacity as a predictor of construction company corporate performance: Evidence from South Africa, *Journal of Engineering, Design and Technology*, 13(**4**), 1-18.

Visconti, R M (2013) Evaluating a project finance SPV: Combining operating leverage with debt service, shadow dividends and discounted cash flows, *International Journal of Economics, Finance and Management Science*, 1(**1**), 9-20.

Wang, G Dou, W Zhu, W and Zhou, N (2015) The Effects of firm capabilities on external collaboration and performance: The moderating role of market turbulence, *Journal of Business Research*, 68(**1**), 1928-1936.

Windapo, A and Cattell, K (2011) *Research Report: Mapping the Path to Becoming a Grade 9 Contractor*, Documentation of Literature and Results of the Upgraded and Established Contractor Interviews, CIDB, Pretoria.

HEALTH AND SAFETY

SHAPING THE FUTURE OF PREVENTION THROUGH DESIGN (PTD) PRACTICE IN THE MALAYSIAN CONSTRUCTION INDUSTRY

Sheila Belayutham[1], Khairil Izam Ibrahim[2], and Azman Hussain[3]

[1&2] *Faculty of Civil Engineering, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia*

[3] *Department of Occupational Safety and Health, Ministry of Human Resources, 62000, Putrajaya, Malaysia*

The Prevention through Design (PtD) Is an emerging safety practice in the construction industry. In Malaysia, Occupational Safety and Health in Construction Industry (Management) (OSHCI(M)) Was launched in 2017 to guide the construction stakeholders to explicitly consider the safety during the design phase and "design out" risks and hazards over a project's lifecycle. As part of a wider study to understand the extent of PtD implementation in Malaysia, this paper aims to discuss what it takes to drive the PtD implementation in line with the OSHCI(M). Qualitative data were collected from civil and structural engineers in Malaysia through focus group discussion based on four series of PtD workshops. From the analysis, three main elements were highlighted, notably the external forces, industry dynamics and operational organisation factors; as push factors that could influence and drive the success of PtD implementation in Malaysia. The findings provide a basis for discussion, both nationally and internationally, to gain greater understanding on driving the fulfilment of OSHCI(M). This study extends the PtD literature in construction context, in particular in developing countries, but also provides insights to interested parties into the advancements to the successful safer design consideration in the construction industry

Keywords: safety, engineers, PTD, H&S, Malaysia

INTRODUCTION

The issue of occupational injuries and fatalities is well acknowledged in construction worldwide. One of the possible contributors to the construction accidents and injuries is the design decisions made in the early phase of the project (Behm, 2005; Tymvios and Gambatese, 2016). Several studies (e.g. Behm, 2005; Haslam, 2005; Driscoll *et al.,* 2008; Hui, 2015) Based on data from the U.S., Europe, Australia and Singapore showed that between 27% and 60% of construction fatalities linked to design-related factors. Consequently, this phenomenon has led many governments to initiate new initiatives to regulate and/or encourage designer to participate in collective responsibilities of the workers and end-user safety.

The *Prevention through Design* (PtD) Concept, also known as design for safety (DfS) Or Safety in Design (SiD) Is one of the prominent ways of leading the fundamental shift of safety practice resulting in greater emphasis on designing out or minimising

[12] chekhairil449@salam.uitm.edu.my

Belayutham, S, Ibrahim, K I and Hussain, A (2019) Shaping the Future of Prevention Through Design (PtD) Practice in the Malaysian Construction Industry *In:* Gorse, C and Neilson, C J (Eds) *Proceedings of the 35th Annual ARCOM Conference,* 2-4 September 2019, Leeds, UK, Association of Researchers in Construction Management, 487-496.

hazards and risks early in the design process (Gambatese *et al.,* 2017; Manu *et al.,* 2018a). The perceived PtD benefits has led to many countries to actively promoting the use of PtD practice in the construction industry.

In Malaysia, attempts to introduce the PtD practice has been initiated by the Department of Occupational Safety and Health (DOSH), under the Ministry of Human Resources, through the establishment of Guidelines on Occupational Safety and Health in Construction Industry (Management) (OSHCI(M)) In early 2017. Established based on the integration of the PtD principles, the guideline embraces the "from the cradle to the grave" concept (i.e. considers the total life span of a building or structure - from the initial concept, design, construction and usage until its demolition) And deemed to be enforced in the coming years.

It is worth highlighting that, the fact that the PtD implementation is part of the objectives outlined in the Construction Industry Transformation Programme (CITP) 2016-2020 under the Quality, Safety and Professionalism thrust: "Initiative Q2b: Improve level of occupational safety and health at construction site", the understanding on what it takes to drive its implementation is significant. If not properly understand, the industry will face significant challenges to diffusion and perceived risks to its implementation (Toole and Gambatese, 2016). *Such risks and challenges include lack of interest from client and designers, lack of safety knowledge among designers, fear of construction liability, conflicts with contractual and procurement arrangements and too many competing priorities during design phase (Tymvios and Gambatese 2016; Toh et al., 2017; Gambatese et al., 2017).*

Despite there were widespread examples of PtD studies and its implementation in various countries (Toole et al., 2017), majority are focused on developed countries and very limited for the developing countries (Manu *et al.,* 2018b). *This is an important gap in the research and practice that has led to barriers in understanding the PtD subject in construction within the developing countries. Given the current limited application of PtD in Malaysia, also of interest are ensuring effective implementation of OSHCI(M), it is important to understand the opinion of all stakeholders, including civil and structural (C&S) Engineers. Being the dominant designers in construction industry in Malaysia, efforts to understand the opinion of C&S engineers cannot be ignored as they are one of the key professionals that responsible to safety and health (according to BEM Code of Conduct of the Registration of Engineers Regulations 1990) And would contribute towards OSHCI(M)'s development and transition in the construction industry. In addition, their role (ensuring the effectiveness of the design and its constructability) in all stages of engineering and construction projects is significant (Toole, 2005).*

Therefore, this paper aims to discuss what it takes to shape the PtD implementation in line with the OSHCI(M). This study is part of a wider study to understand the extent of OSHCI(M) Implementation in Malaysia. *Gaining an insight of how PtD should be drive forward from the designers will facilitate the government and authorities in the dissemination of PtD across the country where formal PtD implementation in construction is gathering pace.*

Emergence of PtD in the Malaysian construction sector

In Malaysia, the Occupational Safety and Health Act 1994 (OSHA) And Factories and Machinery Act (FMA) 1967 is known to be the safety legislative framework for the construction industry. In addition to these legislations, guidelines related to construction safety practices (e.g. Guidelines for Public Safety and Health at

Construction Sites, 2007, Guidelines for the Prevention of Falls at Workplaces, 2007) Have also been established to prevent and control occupational safety and health at construction sites.

Nevertheless, compared to other industries, the construction industry has been documented as having large percentage of fatality rate (i.e. 585 workers were killed at construction sites, between years 2011 and 2016 (Department of Occupational Safety and Health (DOSH), 2017)). Having a disproportionate fatality rate represents a significant threat to the industry's sustainability as well as the business value to construction organisations. Thus, the need to have new initiatives on safety practices in the industry is significant in order to enhance the standards of safety in the construction industry. In particular, the positive impact of PtD practices have led to changes in safety practices and regulatory frameworks of construction safety in Malaysia. The efforts to introduce the PtD practices in the construction industry has started in the early 2017 by the Department of Occupational Safety and Health (DOSH), through the establishment of Occupational Safety and Health in Construction (Management) (OSHCI(M)) Guideline.

It is worth highlighting that the establishment of OSHCI(M) Would add value to the existing Occupational Safety and Health (OSHA) Act 1994 in securing and reducing the discrepancy of responsibility and accountability in compliance to safety guidelines between construction stakeholders. The guideline serves as a guide for individuals with legal duties under sections 15 (General duties of employers and self-employed persons to their employees) And 17 (General duties of employers and self-employed persons to persons other than their employees) Of the OSHA 1994 and further defines their role in compliance with the safety law.

While some countries (e.g. UK and Singapore) Have mandated the use of PtD in their workplace safety legislations, the recently established OSHCI(M) Guideline in Malaysia is based on voluntary approach (similar to the US and Hong Kong) Although is deemed to be enforced in coming years. This would provide ample of opportunities for design professionals in the construction industry to prime themselves with the new requirements and at the same time, acquire knowledge in controlling hazard and risk in the early stages of construction.

The evolution of PtD literature in construction

Research in PtD practice, in particular in the construction domain, has gained increasing attention over the past decades. To identify the literature, we used Scopus databases to search for all publications whose topics cover at least two keywords from the following search string: design for safety"; "safety in design"; "prevention through design" and "construction". In addition, we also referred to the list related to PtD literature (up to June 2016) Compiled by Tymvios (2016). Then, we cross-checked both sources in order to capture the relevant PtD studies in construction context. To trace the patterns and trends, we split the time into five sub-periods and summarise its study context and focus based on its publication year.

The early literature (sub period < 2000) On PtD have emerged from Lorent (1987) Who found that one of the main causes of accidents in construction is the upstream factors (i.e. design activities). The abovementioned report formed the foundation for Council Directive 92/57/EEC to instruct all EU members to focus on the statutory of safety and health in the design process. Research moves from the PtD concept to a wider scope which includes issues such as legal implications, the role of designer and PtD tools. Studies in this period mainly focus on European and US settings.

In sub period (2001 - 2005), the research has broadened its landscape from PtD concept to more empirical-based studies to provide evidence (e.g. linking of fatalities to the design activities) On the PtD practice in construction. Studies begin to focus on diverse subject (e.g. the insurance issue, regulatory / policy issue, Stakeholder (owner / designer), accident causation and PtD education) Through the use of variety methodological approaches. Apart from European and US settings, articles had extended to examine in UK.

In the third sub period (2006 - 2010), the research expands to consider the multiple context in understanding the PtD practice. Scholars begin to examine the impact of PtD on safety standard, role and responsibilities of civil and structural engineers towards PtD and the influence of procurement arrangements on PtD practice. This period also sees the National Institute for Occupational Health and Safety in US began its National Initiative on PtD and in the UK, the CDM Regulations gets its second revision in 2007. Articles begin to examine in Australia setting.

In the fourth sub period (2011 - 2015), the landscape of PtD research has broadened with more analytical-based studies that have provided evidence on the application of PtD in the construction industry of various countries. In particular, there has been a growing research interest on PtD in Australia, UAE and Denmark. In this period, new lines of research have emerged, where scholars have begun to focus on the effect of PtD on social sustainability and the application of tools to be integrated with safety in design practices.

In the fifth sub period (≥2016), more empirical studies aimed to enhance the understanding of PtD among different construction stakeholders in several countries began to develop. In Singapore, since the enforcement of Design for Safety (DfS) Regulation in 2016, studies such as Toh *et al.,* (2017) Have focused on exploring the DfS KAP for multi-stakeholders in the construction industry. In addition, much work in developed countries has also been done in different contexts such as; designers' behaviour on safety in the UK, generating interest for PtD, motivation for PtD and barriers to PtD diffusion. This period also sees the increase in studies conducted in developing countries such as Manu *et al.,* (2018a) And Manu *et al.,* (2018b) Who examined the awareness and practices of DfS amongst architects within the construction sector of Nigeria and Ghana, respectively.

In summary, findings from the construction literatures have widely acknowledged that the subject of PtD is still growing and receiving significant attention (for the last three to five years) In the international prominence (perspective from different stakeholders and different context), although the concept has been introduced over the past few decades. Despite the significant change and improvement in design activities across geographical boundaries over the recent years, there is still a lack of effort to contextualise PtD in the local construction context. As emphasised by Manu et al., (2018a), any empirical studies related to PtD in developing countries (e.g. Malaysia) Would be useful to advance the PtD knowledge within the construction domain.

RESEARCH METHOD

This study was performed in 2018 and first quarter of 2019, as part of an intervention programme initiated in collaboration with the Social Security Organisation (SOCSO) Malaysia, Department of Occupational Safety and Health (DOSH) And Construction Industry Development Board (CIDB) Malaysia. In line with the study's interest in obtaining an overview of a phenomenon, in this case, the key drivers for PtD

implementation in Malaysia, a pragmatic methodological approach through a qualitative method, in particular discussion forums through workshops was adopted. The adoption of the pragmatic approach would be most suitable as having a group discussion (i.e. meeting of a community of practice) Could produce results that can be translated into practical ends (e.g. exploring the drivers to enhance the PtD implementation in the construction industry). Moreover, having workshops as a platform to gather the data collection is possibly the best way as it will enable a greater degree of interaction with participants and also helps in setting expectations. Gathering a group of experts through a workshop in a collaborative and structured atmosphere could assist the engagement with participants who share a common domain and have expectations to achieve something related to their own interests, in this case is the PtD implementation (Gibson and Whittington. 2010; Ørngreen and Levinsen, 2017). It is worth noting that the PtD workshop is believed to be the first of its kind organised in the industry (since the introduction of OSHCI(M)), in collaboration with the regulatory bodies (i.e. DOSH and CIDB) That provide direct consultation and dialogue with C&S professionals.

Four series of PtD workshops (were held on 25th April; 8th and 25th August 2018; and 19 February 2019) With a total of 70 C&S engineers (on average of 17 participants per workshop) Were conducted as a platform to gather data. The purposive sampling of C&S engineer was adopted in this study as the focus of the initial PtD engagement with industry is with the dominant designer in the local construction industry. From the 70 participants, 58% of them described their job functions as engineer and senior engineer, followed by associate director (17%), director (16%) And engineer / OSH practitioner (with certified safety officer) (9%). It is worth noting that 75% of the participant were registered as Civil and Structural Professional Engineer under the Board of Engineers Malaysia (BEM) And the Institute of Engineers Malaysia (IEM). The participants (age ranging from late 20s to 56 years; mean 38 years old) Comprised of 81% (57) Male and 19% (13) Female. In terms of years of experience in the construction industry, the majority of participants had experience between 11 to 20 years (39%). Thirty-four per cent (34%) Of participants claimed to have experience of at least 10 years. This is followed by respondents (17%) Who had experience between 21 and 30 years; and ten per cent (10%) Of the participants had more than 31 years of experience in the industry.

Each workshop was structured with five presentation sessions and one discussion session. The first session was on the introduction of OSHCI(M) (presented by DOSH officer) And the next four sessions were related to PtD modules (presented by four different speakers (two academics with PhD degree in construction; and two academics are certified professional C&S engineers); Module 1: Overview of PtD; Module 2: Processes of Integrating Design and Risk Management; Module 3: Good Design Practices; Module 4: Tools and Resources to Support OSHCI(M) And Health and Safety File). Apart from presenting the relevant contents of the respective module, any questions and issues raised (during the first five sessions) Were noted down. Some of the issues raised (e.g. on the existing culture and behaviours, contracts, best practices, etc.) During the presentation sessions were put forward to the discussion session in order to have an in-depth insight on the matters.

The focus group discussion was conducted at the end of each workshop (last session) And lasted about an hour with the theme of 'shaping the future of PtD practices in the construction industry' in order to capture the C&S engineers' opinion on what it takes to successfully implement PtD in the local construction industry. Each discussion was

coordinated by a facilitator who was from the research team. All the relevant opinions and comments were noted down and analysed in order to realize any differences and commonalities of the findings.

RESULTS AND DISCUSSION

It is evident from the results that despite the early notion among participants that PtD is relatively new concept for them, several areas of commonality were observed and raised by participants in the discussions. The participants' views and thoughts were summarised under three common themes.

External Factors

The first theme identified was the influence of external factors in shaping the PtD implementation. One of the most cited sub-factors in this theme is the PtD education itself. Majority of the participants indicated that although they may have learned the related knowledge on the PtD concept (mainly through their lesson learned and experiences), arrangements to include the subject of OSH in general and PtD concept (e.g. risk, constructability) In particular, should be made during the early professional education i.e. bachelor degree in related civil engineering and built environment courses. It is worth noting that the Engineering Accreditation Council (EAC) In Malaysia dictates that all civil engineering degree programs must demonstrate the graduates meet the 12 specific program outcomes (POs) Where two of the outcomes (PO 3: Design/Development of Solutions and PO6: The Engineer and Society) Explicitly includes the term 'safety'. Nevertheless, based on feedback from participants (professional engineers who experienced as a panellist by EAC) Who have been involved with the accreditation process indicated that the incorporation of safety as a standalone subject is remain elusive. If included, the safety subject is mostly incorporated as a sub topic in a subject such as engineers in society, construction law and only covering the generic context of safety legislation and organisational safety management. The lack of OSH and risk management subject across Malaysia's tertiary education is apparent (Azmi and Mohd Saidin, 2013; van Dijk *et al.,* 2015) And embedding the PtD philosophy in a more widespread education is crucial and central (Toh *et al.,* 2017), as an effort to embrace and correct the fundamentals of PtD knowledge and attitude, not only for future C&S engineers but for all professionals.

Considering the lack of PtD knowledge as well as the awareness of the OSHCI(M) (based on the participant observation throughout the workshops), there is a need for more wider reaching programmes in order to reach-out to the C&S communities. With encouraging interest of acceptance among the participants, continuous PtD training (start with clear, simple and practical modules) Across all key designers is desirable, as an avenue for practical guidance towards enhancing the PtD knowledge and practice (e.g. risk management, communication techniques, hazards control, safety tool and file, etc). The inclusion of lesson learned from real case studies on the impact of PtD and the best practices should be incorporated during the training. Some of the participants recommended that for a start, introductory course (physical or online) Should be introduced as part of the initiative to increase PtD awareness and understanding among the designers. A growing dialogue between clients, constructors and designers on PtD is also preferable (e.g. enhancement of PtD community) As it could offer benefits to all stakeholders on the understanding and improvement of relationship towards PtD practices over time. This is to create a stimulating environment that creates a momentum for a paradigm shift (especially on cultural and

behaviour) In the current industry, towards the adoption of PtD, subsequently the OSHCI (M).

Another sub-factor identified was institutional pressures (e.g. originates from both formal rules (regulations, mandates) And informal constraints (norms, conventions, beliefs)). These pressures could influence the behaviour of project clients/owners and could extent to project-level PtD adoption. Based on the feedback, the participants claimed that project owners/client could play a major role in advocating this practice since they hold the power to control (i.e. operational) And fund construction projects. In addition, formal engagement with professional bodies (i.e. BEM and IEM) Is also highlighted as important process in order to ensure the support from the engineer's board. Any negative responses from the board would discourage the designer to adopt and adapt the practice. It is worth noting that the consideration to legally enforce the use of PtD has already been proposed by DOSH to be implemented in coming years. This effort is important as without legal enforcement, establishment of the PtD duty of care for designers and their responsibilities loses its potency (Kamardeen, 2015; Manu *et al.,* 2018a). The regulatory bodies (e.g. CIDB, DOSH and BEM) Have also explored other initiatives including mandatory completion of an OSHCI(M) Course as a registration requirement for professional designers. In addition, the professional assessment and competency examination could potentially be expanded to include the PtD context.

Industry Dynamism

The second theme identified was industry dynamism. There is widespread recognition that existing contractual and procurement framework is insufficient to embrace the collaborative and collective movement (e.g. PtD, BIM) In the industry. One of the most significant feedbacks from the discussion was that despite the existing OSH BQ in CIDB, (Guideline for OSH specification's schedule of prices), Public Works Department (PWD) (specification for OSH for Engineering Works 2011), DOSH (Guideline on contract management) and on-going development of standardised OSH BQ for government projects to improve the aspect of cost for safety, the issue on designers' liability insurance coverage, remuneration and professional fees still remains a significant concern to the designers. Such standard or contract could help to further develop the boundaries and the functions of safe design practice.

On the procurement side, the lack of contractors' involvement in design phase is highlighted as one of the main barriers for PtD implementation. The introduction of more collaborative procurement approaches (e.g. partnering, alliance and early contractor involvement) Is vital to help the industry players to embrace the collaborative movement towards positive PtD attitude and practice. The adoption of advanced procurement system will enhance the boundaries of safety roles and responsibilities at all hierarchy levels (Larsen and Whyte, 2013). Past studies (e.g. Toole *et al.,* 2017; Tymvios and Gambatese, 2016) Suggest that the ability to establish appropriate contractual arrangements will ensure the potential benefits (e.g. access the constructability at early stage, integration of safety among actors, clear about liabilities, contract terms etc) As PtD implementation would be maximised successfully.

The subject of having a single point of responsibility (i.e. independent coordinator / consultant) To manage the PtD implementation (e.g. the same experiences with Singapore) Has also been raised during the discussion as this approach could change the dynamic safety capability within the industry. While some of the participants

believed that this approach will create a new kind of employment with new lines of safety responsibility (with PtD professional certification), as well as ensuring systematic and comprehensive PtD implementation, while others have indicated that principal designers in the project should be the ones shouldering the responsibility. Moreover, local designers *would require specific safety knowledge about equipment and methods used in their geographic state to in line with any safety rules under Uniform-Building-by-Law (UBBL).* The reliance on independent consultants will revert the process back to the old safety culture, instead of moving forward towards proactive actions of PtD.

Operational organisation factors

The third theme was operational organisation factors, where the majority of participants pointed out that the use of digital application such as Building Information Modelling (BIM) Is one of the critical success factor for PtD implementation as it could alter the construction terrain and create new opportunities for improving productivity and safety at the early stages, and hence holds significant potential for supporting the fulfilment of OSHCI(M). Similarities in the aims of OSHCI(M) And BIM are self-apparent. For example, information on client or authority's requirements or specifications could be incorporated into designers' BIM model (digitally connected to the design engineers) And construction simulations could open-up the potential for identification, coordination and facilitation of health and safety checks and requirements. Such tools could assist the design decision during the planning and hence maximizing the safety of worker during operational phase (Toole, 2005). Moreover, as BIM level 2 has been introduced as a requirement for all government construction projects (valued more than RM 100 millions) By 2019, the collaborative effort towards enhancing safety practices is timely.

The subject of enhancing capacity building within the organisation has also been highlighted due to the fact that PtD is a new practice in the industry. One of the most cited factors is the lack of support and encouragement from the organisation to support the safety exercised during the design process due to other priorities. This scenario indicates the lack of awareness and capability of the organisation with regard to the safety aspect. Nurturing the safety capability through education and continuous training (Tymvios and Gambatese, 2016; Toh *et al.,* 2017) Is critical in order to build a risk sensible culture at all safety decision making levels. In addition, ability to monitor the capability and capacity of the organisations for PtD implementation over time is also vital for continuous improvements. Having such culture and capability could shift the organisation from the compliance approach to a more proactive and leading approach.

Overall, it can be seen that industry practitioners enrich the way forward for PtD implementation in more practical manner in order to suit the local context. In fact, despite that the concept is relatively new to the industry, they broaden the driver to include not only issues such as related to technological and legislative perspectives but also softer or non-technical aspects as the drives of PtD practice.

CONCLUSIONS

This paper has identified how *the PtD practice can be put forward for better implementation in line with OSHCI(M) In the local construction industry, based on studies of opinion from C&S engineers through three series of group discussions. In general, the practitioners agreed that PtD is a feasible intervention practice that need*

to be introduced as part of collective movement in improving the safety and health of workers.

The finding generates insights on the key elements for PtD diffusion, notably the external forces, industry dynamics and operational organisation factors. The first element, external forces, is related to early PtD education, platform for continuous engagement and institutional pressures. The next dimension, industry dynamics is focused more on the influence advance contractual and procurement framework as well as having PtD coordinator. The last dimension, operational organisation is related to the availability of PtD tools that would enable the PtD practice and nurturing the organisational PtD capability. By paying attention to these elements, it is possible for the regulatory bodies and construction organisations to instil positive safety practices among the C&S engineers, towards a paradigm shift of impacting the safety performance in the construction industry (i.e. Construction Industry Transformation Programme (CITP) 2016-2020 under the Quality, Safety and Professionalism thrust: "Initiative Q2b: Improve level of occupational safety and health at construction site").

Nevertheless, in acknowledging that the key elements are contextually embedded and only based on small number of population, further research could expand the current population to larger scales with diversified samples (e.g. clients, architects, developer, contractors) As well as focusing on qualitative methodologies (e.g. focus group, case studies) To facilitate more practical and informative findings in *understanding the impact of PtD practice towards the fulfilment of OSHCI(M).*

ACKNOWLEDGEMENTS

This work described in this paper has been partly funded by the Social Security Organisation (SOCSO) Malaysia under Safety and Health Grant (Ref No. PKS/PPKP/(S)/208/24/2 (70)).

REFERENCES

Azmi, W M and Mohd Saidin, M (2013) Designer's safety curricula for undergraduate students, *American International Journal of Contemporary Research, 3(**11**), 115-121.*

Behm, M (2005) Linking construction fatalities to the design for construction safety concept, *Safety Science*, *43*(***8***), 589-611.

DOSH (2017) *OSH in Construction - Prevention Through Design (PtD) Year 2017, Issue 1*, http://www.dosh.gov.my/index.php/en/list-of-documents/osh-info/construction-safety/e-buletin/2017/2382-bil-1-2017-prevention-through-design/file [Accessed 15th December 2018].

Driscoll, T R, Harrison, J E, Bradley, C and Newson, R S (2008) The role of design issues in work- related fatal injury in Australia, *Journal of Safety Research*, 39(***2***), 209-214.

Gambatese, J A, Gibb, A G, Brace, C and Tymvios, N (2017) Motivation for prevention through design: Experiential perspectives and practice, special collection on construction safety, Practice Periodical on Structural Design and Construction, 22(***4***), 04017017.

Gibson, G E and Whittington, D A (2010) Charrettes as a method for engaging industry in best practices research, *Journal of Construction Engineering Management*, 136(***1***), 66-75.

Haslam, R A, Hide, S A, Gibb, A G F, Gyi, D E, Pavitt, T, Atkinson, S and Duff, A R (2005) Contributing factors in construction accidents, *Applied Ergonomics*, 36(***4***), 401-415.

Hui, T T (2015) *Accidents That Can Be Prevented Through Design and Examples of DfS*. DFS Forum, 21 Oct 2015. Available from https://www.wshc.sg/files/wshc/upload/event/file/4_DfS_examples.pdf [Accessed 10 December 2018].

Kamardeen I (2015) *Fall Prevention Through Design in Construction: The Benefits of Mobile Computing*. Abingdon, UK: Routledge.

Larsen, G D and Whyte, J (2013) Safe construction through design: Perspectives from the site team, *Construction Management and Economics*, 31(***6***), 675-690.

Manu, P, Poghosyan, A M, Agyei, G, Mahamadu, A M and Dziekonski, K (2018b) Design for safety in construction in sub-Saharan Africa: A study of architects in Ghana, *International Journal of Construction Management*. Available from https://doi.org/10.1080/15623599.2018.1541704 [Accessed 8/7/2019]

Manu, P, Poghosyan, A M, Mshelia, I M, Iwo, S T, Mahamadu, A M and Dziekonski, K (2018a) Design for occupational safety and health of workers in construction in developing countries: A study of architects in Nigeria, *International Journal of Occupational Safety and Ergonomics*, 25(1), 99-109.

Ørngreen, R and Levinsen, K (2017) Workshops as a research methodology, *Journal of E-Learning*, 15(***1***), 70-81.

Toh, Y Z, Goh, Y M and Guo, B H W (2017) Knowledge, attitude and practice of design for safety: Multiple stakeholders in the Singapore construction industry, *Journal of Construction Engineering and Management*, 143(***5***), 04016131.

Toole, T (2005) Increasing engineers' role in construction safety: Opportunities and barriers, *Journal of Professional Issues in Engineering Education and Practice,* 131(***3***), 199-207.

Toole, T M, Gambatese, J A and Abowitz, D A (2017) Owners' role in facilitating prevention through design, *Journal of Professional Issues in Engineering Education and Practice*, 143(***1***), 04016012.

Tymvios, N (2016) *Prevention Through Design (Ptd) Literature*. https://designforconstructionsafety.files.wordpress.com/2017/05/prevention-through-design-lit-june-2016.docx [Accessed 5 January 2019].

Tymvios, N and Gambatese, J A (2016) Direction for generating interest for design for construction worker safety - A Delphi study*, Journal of Construction Engineering and Management*, 142(***8***), 04016024.

van Dijk, F J, Bubas, M and Smits, P B (2015) Evaluation studies on education in occupational safety and health: Inspiration for developing economies, *Annals of Global Health*, 81(***4***), 548-560.

CONCEPTUAL ARGUMENT ABOUT DRIFT INTO FAILURE MASKED BY WORK PRESSURES ON CONSTRUCTION SITES IN SOUTH AFRICA

Fidelis Emuze[1]

Department of Built Environment, Central University of Technology, Free State, Private Bag X20539, Bloemfontein, 9300, South Africa

A 'drift into failure' is a gradual decline in safe work procedures (SWPs). The decline in SWPs is driven by workplace factors, which include safety violations on construction sites. This paper conceptually argues against work pressures that lead to safety violations. The argument is based on the premise that violations move construction practices incrementally towards the edge of safety boundaries. The reported research in this paper followed an inductive. A semi-structured instrument was used to collect data from face-to-face interviews conducted in a province in South Africa. The interviewees were twenty-five construction professionals with on-site experiences. The analysed textual data revealed that safety violations were embedded in site operations. The results also reveal that unsafe procedures existed as part of regular work routines in South African construction. The underlying causes of the violations mentioned by the interviewees included: intoxication, fatigue, negligence, work pressures and the refusal to adhere to SWPs. The most cited cause was work pressures that required operatives to increase productivity at the expense of safety. It was apparent that work pressures mask the normalisation of safety violations that drives the drift into failure. The conceptual argument reinforces the idea that persistent work pressures with which site operatives contend during construction drive a drift into failure. Therefore, contractors must implement practical measures that will limit drift to unsafe procedures. A measure that is at the centre of the matter is the need to discourage cutting corners in favour of increased production rates while ensuring that work pressure is not excessive on site.

Keywords: compliance, drift into failure, safety, site work, violations

BACKGROUND

The management of health, safety and well-being (HSW) is not exempted from the dynamic nature of the human mind despite the goal of eradicating harm. The human contributions to accidents and the potential for resilience are well reported (Reason, 2008; Hollnagel, Woods and Leveson, 2006). The proliferation of an unintentional course of events is shaped by what people do. What people do either trigger an accidental flow of events or alter a regular flow of SWP. The management of HSW, then, depends on the control of work processes (for instance, through the flow of information and materials in construction) to avoid unintended events that could harm people.

The control of activities in a workplace that is always in a state of change and modification is not an easy task. Rasmussen (1997) says that the control of activities

[1] femuze@cut.ac.za

Emuze, F (2019) Conceptual Argument about Drift into Failure Masked by Work Pressures on Construction Sites in South Africa *In:* Gorse, C and Neilson, C J (Eds) *Proceedings of the 35th Annual ARCOM Conference,* 2-4 September 2019, Leeds, UK, Association of Researchers in Construction Management, 497-506.

to ensure safety through a prescriptive approach is only useful in a static setting where instruction and procedure are based on task analysis. In contrast, regulations and procedures for work in complex systems are always incomplete, and frontline operatives must sometimes deviate from the work as imagined (WAI). The deviations might be required by conditions that were not anticipated by the writers of an SWP. Such conditions would make frontline workers develop 'workarounds' to get the job done. Other deviations result in workers taking shortcuts to either reduce workload or improve productivity (Dekker, 2011). Deviations, which are a violation of SWP, start a slow drift into failure with multiple steps that occur over an extended period (Dekker, 2011; Stoop, 2018). The extended period is called the 'incubation period' (Rasmussen, 1997; Stoop, 2018). Each step in the period is usually negligible, so it goes unnoticed, in the absence of a significant event, until it is too late. Deviations from work routine thus occur in the face of increasing competitive pressure and resource scarcity. For example, Dekker (2011) and other scholars say that regular people, who come to work each day to do a regular job, could deviate from SWPs because of work pressures.

In this paper, the 'drift into failure' theory is used to make a conceptual argument that work pressures encourage safety violations on South African construction sites where fatalities are continuously recorded (Emuze, van Eeden and Geminiani, 2015; 2017; News24, 2019). The 'drift into failure' theory refers to a gradual decline into a tragedy compelled by environmental pressure, rapidly changing technology and social processes that normalise increasing exposure to safety risk (Dekker, 2011). For instance, the issues relating to work-as-imagined versus work-as-done (WAI/WAD) and the need to balance rules with situational realities could be explained by stating that drift into failure had occurred in the case of an accident because preventing hazardous activities requires rules, procedures and standards to specify safe ways of operating (Stoop, 2018).

The discussion of theory in this section is followed by an explanation of the research method used to collect the primary data. The results, as presented, reinforce the perception that safety violations occur on different sites in South Africa (Emuze, 2018). In a discussion of work pressures, the case is made for employing the preventive measures advocated in practical drift theory. The preventive measures are outlined in conclusion to this paper.

RESEARCH METHOD

An inductive approach (qualitative research) was used for this study. Qualitative research is a broad term for a range of methods that vary in terms of focus and assumptions about the nature of knowledge (Astalin, 2013). The method is characterised by a stated aim, which relates to understanding aspects of social life and, in general, its techniques generate data in the form of words rather than numbers for analysis. In essence, phenomenological, qualitative research was conducted to gain a better understanding of the safety violations embedded in the routine work of site operatives. The goal of phenomenological research is to describe a lived experience of a phenomenon such as safety violation. The primary data were collected from construction sites. The use of a qualitative, interpretive approach assisted the study in the sense that the collection of data was based on the social and contextual beliefs of the participants. The research conformed to the idea that carrying out a qualitative study places the observer in the context of the phenomenon being observed (Denzin and Lincoln, 2008) which, in this case, was various construction sites.

The research involved interpretive practices based on interviews and field notes (Denzin and Lincoln, 2008). The interviews were conducted using a semi-structured guide that elicited information from construction professionals. For this study, the primary question was: How do safety violations become embedded in the work of artisans and their supervisors on a construction site? The secondary questions used to explore the phenomenon were grouped under the themes shown in Table 1.

Table 1: Themes and related questions used to collect primary data

Theme	Questions used to compile each theme
Understanding health and safety violations by supervisors on a construction site.	How would you describe H&S on site?
	What would you describe as the main factor causing accidents in construction?
	What do you understand by the term safety violations?
	Why do supervisors violate safety rules?
	What is the role of supervisors regarding H&S?
	What do you understand about working conditions on sites?
Understanding health and safety violations by artisans on a construction site.	How would you describe the attitude of artisans towards accidents?
	Would you say safety violations lead to accidents?
	What impact do accidents have on work output produced by artisans?
	What would you suggest should be done to encourage artisans and supervisors to mitigate the causes of accidents on site?
	Do workload and pressure influence the extent of safety violations on sites?
	What sort of interventions should be undertaken by supervisors to make sure artisans adhere to safety rules?
	What are the common accidents caused by site operatives in your workplace?
Adherence to and compliance with safety regulations	Is H&S legislation and regulation promoted on your site?
	How often are education and training provided on your site?
	Do you have motivating programmes for H&S compliance?
	How committed is management to making sure site operatives comply with H&S regulations?
	How do you address non-compliance?

All the interviews were conducted face-to-face, and they were all tape-recorded and transcribed. The purposively selected interviewees were identified through their involvement in on-going projects in 2018. Although 30 people were approached, only 25 interviewees (with 20 males and 5 females) participated in the study. The number of interview data was acceptable for analysis, as suggested by Yin (2013). The sample included 18 interviewees working for contractors on site, while three worked for consultants, and four of them worked for public entities (clients). The interviewees included site managers, site agents, general foremen, safety officers, building inspectors, project managers, artisans and general workers. Of the interviewees, 21 had more than five years' work experience in the construction

industry, while 16 of them had tertiary, built environment qualifications as their highest degrees or diplomas.

A team of research assistants was used to collect data from several construction sites in the Chris Hani District Municipality area, in the Eastern Cape Province of South Africa to promote stronger substantiation of feedback to the research questions. The use of three field workers to collect data using the same instrument improved the credibility of the findings (Huberman and Miles, 2002). The nature of the data guided the thematic analysis of the data. The analysed data indicated the extent of safety violations based on the lived experiences of the interviewees. The interpretation of the data based on lived experiences provided a better understanding of the main issues related to the research topic (Huberman and Miles, 2002).

FINDINGS AND INTERPRETATIONS

In this section, the findings based on the perceptions of the interviewees have been interpreted. The focus of the themes outlined below was on responses to safety violations committed by site operatives (artisans and their supervisors). The section thus provides the basis for the subsequent discussion on a drift into failure.

Theme 1: Understanding H&S violations by supervisors on construction sites
In response to the questions under Theme 1, the interviewees described the causes of safety violations that they have encountered on their sites. The following comment by an H&S officer was insightful:

> The main factor that causes accidents on site is when both employer and the employees do not follow or rather neglect the health and safety rules and regulations. Deliberately neglecting set safety procedures endangers every personnel on site. Other factors may be taking shortcuts when doing an assigned job. Shortcuts that are taken on the job are no shortcuts; they are merely increasing the risk of injury or, worse, death…

The interviewees, in general, concurred that overlooking safety precautions on a construction site could lead to unfortunate events. For example, a safety manager noted that either fatigue or intoxication was a significant cause of accidents recorded by site operatives on construction sites. Other causes mentioned by the interviewees included negligence, unidentified hazards in the workplace and human error.

In addition, most of the safety professionals that were interviewed regarded safety violations to be acts or omissions that compromised safe working conditions and procedures in contravention of relevant policies and regulations. The textual data also showed that supervisors tended to violate construction H&S rules to increase production. The push for higher levels of production led to situations where they would cut corners and endanger people to achieve handover dates. In most cases, the rules were violated when work was conducted under pressure as a result of poor planning. An H&S officer stated that supervisors tend to deliver a high level of production output without taking the HSW implications of the pace of work into consideration.

When the interviewees were asked about the H&S role of supervisors, three site managers were of the view that supervisors must inform workers of dangerous situations and shortcomings in the workplace to ensure that a safe working environment is provided. One manager indicated that continuous monitoring is essential to assess whether construction is proceeding in a safe environment. The idea from this site manager correlated with that of another interviewee (also a site

manager) who contended that the role of supervisors is to inspect workplaces and direct workers to ensure that people and materials/property are safe at all times. In response to the question of what the interviewees understood about working conditions on construction sites, five of them reasoned that the working conditions on sites with records of injuries and accidents were often risky. It is notable that a site agent believed that every worker should be entitled to a safe working environment where they are not subjected to working in severely cold or scorching conditions.

Theme 2: Understanding H&S violations by artisans on construction sites
The focus of the questions under Theme 2, listed in Table 1, was on artisans. Some of the interviewees were of the view that artisans generally ignore safety and always claim that they know what they are doing because of their years of experience. The reference to years of experience as an excuse to deviate from SWPs represents an inappropriate state of mind or way of thinking. A safety manager with ten years' work experience suggested that all accidents involving artisans are caused by non-compliance with the H&S plan because of pressure and deadlines to complete the jobs. The other ninety per cent of the respondents agreed that the perception that safety violations by artisans were causing accidents was an accurate reflection of what was happening on site.

Although one site engineer perceived that artisans were generally pro-active towards accident prevention, the tendency of artisans to ignore SWP when under pressure to increase production is always a concern. In support of this perception, another site manager believed that H&S was not a concern for artisans and stated: 'it seems that, as long as production is done, the rest does not matter, and this complicates the role of the supervisor.' Overall, the interviewees agreed that workload and work pressure influenced the extent of safety violations on sites. The first interviewee was of the view that, to some extent, the main reason for safety violations was improper planning of construction operations, which leads to abnormal workload and pressure. An interviewee with ten years' experience in the industry also confirmed that supervisors were under pressure from contractors to meet specific deadlines which, in turn, put pressure on the workers. The gravity of the influence of work pressure on safety was emphasised by the following verbatim responses to the question: 'Do workload and pressure influence the extent of safety violations on sites?':

> Yes, arrogance and carelessness are causing work pressures to produce more, thus violating safety rules.
>
> Yes, it is common to experience violations when the work is behind schedule as some safety compliance takes time, which the contractor may not have.
>
> Tight deadlines create a perfect environment for accidents. Unsafe acts and fewer safety checks often accompany it.
>
> A lot, because supervisors and artisans are violating safety measure due to taking shortcuts and leaving materials recklessly.
>
> Yes, they do. If workers are overworked, and they are tired, they tend to take shortcuts and shortcuts at the workplace are a safety violation, which may lead to accidents/incidents.

It was evident from the above quotes and other transcribed data that the interviewees agreed that work pressure leads to safety violations in construction. The interviewees also agreed that accidents have a devastating effect on the progress of construction work. Thus, workload and pressure lead to safety violations that beget accidents which, according to the interviewees, include falling from scaffolding, cuts and bruises, trips and falls, and being struck by bricks while doing brick 'tossing' between

workers. To curb these accidents, most of the interviewees suggested that wearing the required personal protective equipment (PPE), maintaining a high standard of housekeeping, and monitoring construction activities should not be compromised. Furthermore, the interviewees suggested that site operatives should not compromise the purpose of toolbox talks and early warning signs. A few interviewees also mentioned increased awareness and training.

Concerning interventions that should be implemented to ensure that artisans abide by safety rules, the interviewees perceive that supervisors should ensure that SWP training is conducted to reinforce the implementation of method statements for every activity on site. They also suggested that the daily safe task instruction (DSTI) should be provided to support compliance-based safety.

Theme 3: Adherence to compliance and safety regulations
As shown in Table 1, Theme 3 was based on questions that addressed how greater compliance could discourage safety violations. One interviewee suggested that safety agents carry out bi-weekly audits with the help of a safety officer who is resident on site. Another interviewee suggested daily inspections, safety file updates and toolbox talks as ways of promoting compliance. However, most interviewees appeared to be unsure of what could be done to deter safety violations on their sites. Eight of the interviewees mentioned that they had programmes that encouraged and motivated workers to be safety compliant. For example, a safety manager alluded to an H&S monthly reward system that was used in his organisation to motivate workers. However, ten interviewees noted that their companies did not have such a system. Seven interviewees were undecided in their responses to the questions. The seven interviewees neither confirmed nor refuted the existence of a programme that encouraged compliance with safety procedures in their firms.

Regarding the frequency of training provided on site and who does the training, most of the interviewees said that it was done weekly. The interviewees considered on-going education and training to be a reliable way of preventing safety violations. In particular, a site manager argued that continuous education and training is necessary because employee turnover is very high in the industry where supervisors are often responsible for on-site training. Apart from supervisors, safety officers also provide the required training on specific sites. Some of the interviewees confirmed that safety officers could train workers because contractors employ them on a full-time basis.

DISCUSSION

The results in the previous section are relevant to all project role-players in South African construction. Concerned managers and operatives should consider: 'why do people in the frontline of construction take shortcuts and put themselves at risk?' The above results indict supervisors who put immense pressures on artisans to complete tasks. The findings confirm the perceptions of safety professionals from different industrial sectors. In particular, in response to a similar question posed to 66 safety professionals in different industrial sectors, Carrillo (2013) determined that human nature, leadership and culture, production/financial pressures, and operational/management systems constitute the reasons why people take shortcuts and put themselves at risk. These factors are inter-related as they influence production pressures, which have been highlighted as a leading cause of unsafe acts and human failures (errors and violations) in construction (Alper and Karsh, 2009; Lingard *et al.,* 2016). The four factors identified by Carrillo (2013) also drive a drift into failure in the workplace. It is notable that the drift is not caused by the evil tendencies of people

to cause accidents (Dekker, 2011; Stoop, 2018). Instead, the drift is a natural phenomenon that affects all types of adaptive systems, including the construction process where supervisors and artisans are critical role-players.

Drift into failure, which is also known as 'practical drift' (Snook, 2000; Rasmussen, 1997), is a theory that provides direction for activities that could address the unpredictable nature of workplace practices that results in accidents. The reporting of industrial accidents, both in empirical sources and in mainstream media, often mentions one form of violation or another. It might be difficult to accept (especially on a construction site) that managers and workers are always modifying their actions according to the perception of what is required to get the job done. Deviations from SWPs are a pathway to loss of control in the workplace. In addition, injuries and fatalities on an industrial worksite are the results of the loss of control of physical processes that can harm people and damage properties (Rasmussen, 1997). Many scholars, such as Hollnagel *et al.,* (2006), attest to the notion that rules and procedures are an attempt to uphold consistency that keeps workers safe. However, this notion is only valid to the point where the human mind shifts to a new perception of what is required in the workplace (Carrillo, 2013).

The mind shift is influenced by competing priorities and constraints that affect socio-technical systems, such as: what is achievable in the construction process? When a construction system, for instance, is subjected to multiple pressures, the acceptable boundary for safe performance can move over time in response to different events. The movement is a feature of adaptive systems. The drift into failure theory is a metaphor that characterises adaptive systems. The theory explains why people work as they do, what they believe is essential for safety, and which pressures can incrementally erode safety (Marsden, 2018). The theory points to the idea that safety is a problem of control, which incorporates underlying dynamics that slowly lead to accidents (Dekker, 2011; Marsden, 2018).

The underlying dynamics of safety as a problem of control are illustrated in Figure 1. The main feature of the figure is the space of possibilities formed by three constraints (Rasmussen, 1997). The figure shows three scenarios. In the first scenario, management pressurises workers to perform work efficiently to avoid economic failure (1 of 3 in Figure 1). In this case, Marsden (2018) says that the competitive environment forces managers to focus on short-term financial success that guarantees business survival, rather than on long-term imperatives such as safety. In the next scene where workers expend the least effort, the possibility of bankruptcy for an organisation is real (2 of 3 in Figure 1). When both economic and unacceptable workload pressures push work to migrate towards the limits of safe performance (3 of 3 in Figure 1), the system gradually drifts into practical failure, and the result is an accident caused by unsafe acts (violations and errors) and conditions (Marsden, 2018; Rasmussen, 1997). The normalisation of violation accelerates the drift into failure in the illustration.

Dekker (2011) and the interviewees in the previous section mentioned that safety violations are perpetrated by workers who take shortcuts either to reduce workload or to improve productivity. Over time, safety violations become normalised as routines (Reason, 2008; Stoop, 2018). The normalisation of violations leads to a steady disengagement of practice from SWPs as WAI changes to WAD (Snook, 2000). Therefore, attention to violations and the tendency to normalise them in construction should be addressed because "maintaining safety outcomes may be preceded by as

many procedural deviations …" (Dekker, 2004: 133). Attention to violations is required because work pressure drives the drift away from the safety margins because of the need for a faster rate of work completion. Some firms do not view violations as a shortcoming; instead, they view them as an indication of the increased motivation of the operatives. Such views should be discouraged on construction sites.

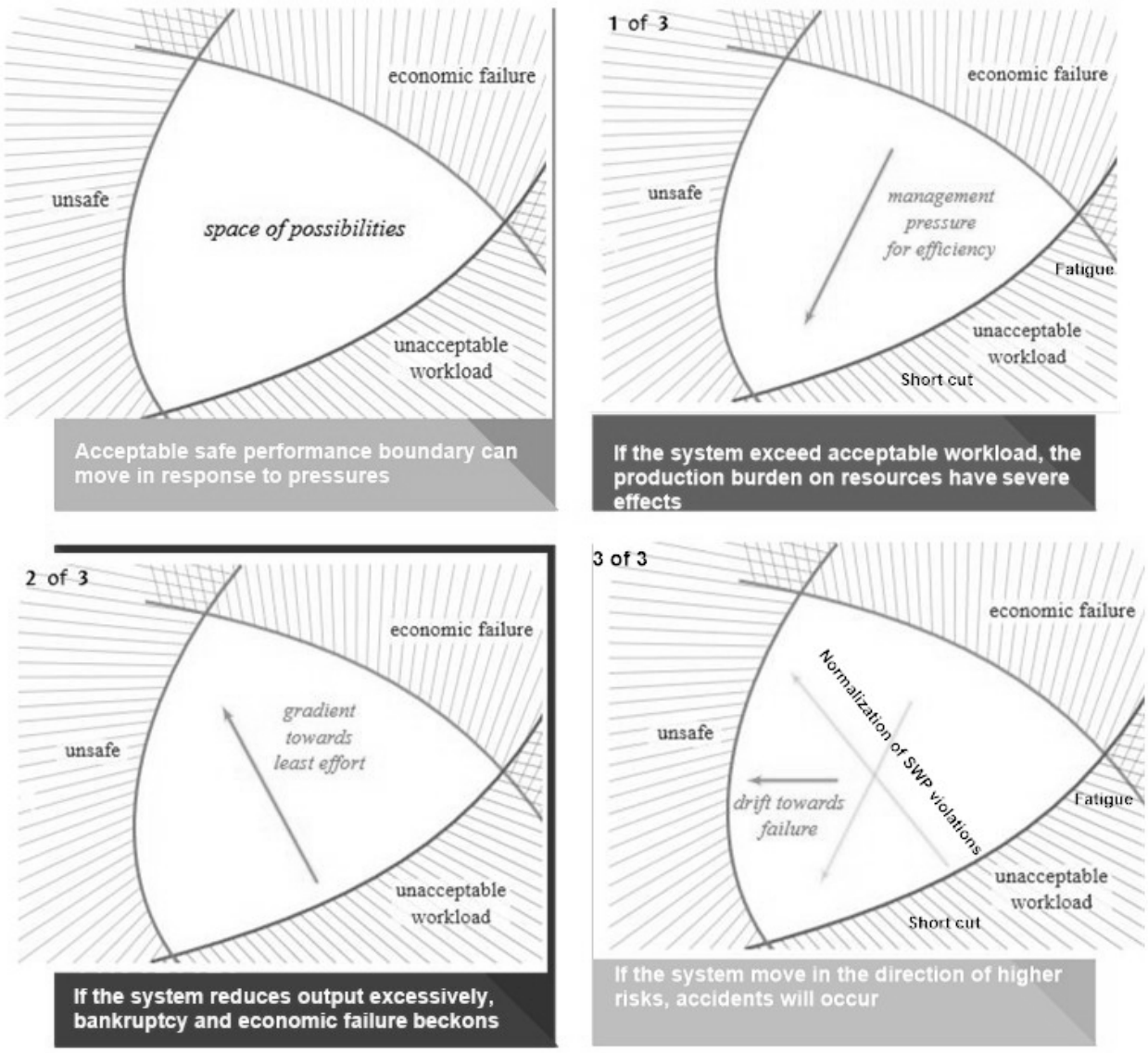


Figure 1: Illustrated space of possibilities concerning drift into safety failure (Adapted from Rasmussen, 1997; Marsden, 2018)

CONCLUDING REMARKS

Safety violations and errors are the principal constituents of human failure. These constituents are the mechanisms by which people contribute to accidents in various industries. The reported research confirms in this paper that site operatives perpetrate safety violations in South African construction. Fatigue, substance abuse (intoxication), negligence, unidentified hazards (or ignorance about hazards), and work pressure were mentioned as the factors causing site operatives to perpetrate safety violations. The interviewees reiterated the detrimental effect of work pressure that supervisors exert on artisans and general workers on sites. The view of the interviewees supports the proposition of Rasmussen's migration model (Figure 1), which shows that small compromises and adaptations can accumulate over time

(referred to as the incubation period) to create situations that erode safety. The conceptual argument is that, if there were no countermeasures to the normalisation of SWP violations, safe systems would drift towards practical failure, i.e. accidents.

The factors that contribute to drift into failure, combined with the normalisation of safety violations, are related to work pressure. Work pressures that override HSW concerns result in incremental tolerance for shortcuts that lead to improved productivity in the short term. The shortcuts also lead to the bypassing of safety barriers during periods of high workload. In sum, site operatives must be aware of, and avoid, these factors with the support of management on a project. Contractors also must discourage cutting corners on their project sites. Apart from discouraging cutting corners, contractors have to implement practical measures that give safety an active voice on a site to limit drift towards unsafe procedures. Managers and supervisors must stay alert to repeated failure on site to address the normalisation of SWP violations. The alertness of site management should flag and stop mixed (contradictory) safety messages and empower workers to report deviations from SWPs. The empowerment of site operatives should encourage a just culture that allows everyone to report hazards and near misses that could have resulted in the loss of control. Prevention of loss of control will limit injuries and fatalities on sites.

It is, however, important to highlight a limitation of this argument because safety violations are only one component of the practical drift towards accidents. There are other components of drift into failure. All the components of drift into failure can alter perceptions of risk, priorities, decision-making and actions in an organisation. Therefore, there is significant scope for addressing the theory in the context of operations management in construction.

ACKNOWLEDGEMENTS

In developing this paper, the author has drawn on research work assigned to his students in 2018. The author gratefully acknowledges C Mkabile, BM Hlangane, and NE Mdunyelwa. The contributions of the two anonymous reviewers of the abstract and the paper are also appreciated.

REFERENCES

Alper, S J and Karsh, B-T (2009) A systematic review of safety violations in industry, *Accident Analysis and Prevention*, 41(**4**), 739-54.

Astalin, P K (2013) Qualitative research designs: A conceptual framework, *International Journal of Social Science and Interdisciplinary Research*, 2(**1**), 118-124.

Carrillo, R (2013) *Practical Drift: Why People Don't Always Follow Procedure and Can Relationship-Based Safety Help*? Available from https://blog.predictivesolutions.com/blog/practical-drift-why-people-dont-always-follow-procedure-and-can-relationship-based-safety-help [Accessed 25 February 2019].

Dekker, S W (2004) *Ten Questions about Human Error: A New View of Human Factors and System Safety*. New York: CRC Press.

Dekker, S (2011) *Drift into Failure from Hunting Broken Components to Understanding Complex Systems*. Farnham, UK: Ashgate Publishers.

Denzin, N K and Lincoln, Y S (Eds,) (2008) *Collecting and Interpreting Qualitative Materials 3rd Edition*. Thousand Oaks, CA: Sage.

Emuze, F (2018) Foreseeing Countermeasures for Construction Safety Violations in South Africa. *In:* Gorse, C and Neilson, C J (Eds.), *Proceedings 34th Annual ARCOM Conference*, 3-5 September 2018, Queen's University, Belfast, UK. Association of Researchers in Construction Management, 587-596.

Emuze, F, Van Eeden, L and Geminiani, F (2015) Causes and effects of building collapse: A case study in South Africa, *In*: M Behm and C McAleenan (Ed.) *CIB W099 International Health and Safety Conference*, 9-11 September 2015, Belfast, UK, 407-16.

Emuze, F A, Van Eeden, L and Geminiani, F (2017) A South African case study on the causes of building collapse, *Journal of Construction*, 10(**4**), 11-28.

Huberman, M and Miles, M B (Eds.) (2002) *The Qualitative Researcher's Companion*. Thousand Oaks, CA: Sage.

Hollnagel, E, Woods, D D and Levenson, N G (Eds.) (2006) *Resilience Engineering: Concepts and Precepts.* London, UK: Ashgate Publishing.

Lingard, H, Pink, S, Hayes, J, McDermott, V and Harley, J (2016) Using Participatory Video to Understand Subcontracted Construction Workers' Safety Rule Violations. *In:* Chan, P W and Neilson, C J (Eds.), *Proceedings 32nd Annual ARCOM Conference*, 5-7 September 2016, Manchester UK. Association of Researchers in Construction Management, 457–466.

Marsden, E (2018) *Rasmussen and Practical Drift*. Available from https://risk-engineering.org/concept/Rasmussen-practical-drift [Accessed 25 February 2019].

News24 (2019) *3 Killed as Wall Collapses on Construction Site in Isipingo*. Available from https://www.news24.com/SouthAfrica/News/3-killed-as-wall-collapses-on-construction-site-in-isipingo-20190218 [Accessed 26 February 2019].

Rasmussen, J (1997) Risk management in a dynamic society: A modelling problem, *Safety Science*, 27(**2/3**), 183-213.

Reason, J T (2008) *The Human Contribution: Unsafe Acts, Accidents and Heroic Recoveries*. Farnham, UK: Ashgate.

Snook, S A (2000) *Friendly Fire*. Princeton, NJ: Princeton University Press.

Stoop, J (2018) Drift into failure, an obsolete construct, *Advances*, 1(**1**), 99-117.

Yin, R K (2013) *Case Study Research: Design and Methods*. London: Sage Publications.

IMPLEMENTING A COMPRESSED WORKING WEEK IN THE IRISH CONSTRUCTION INDUSTRY: PERCEIVED IMPACT ON HEALTH AND WELLBEING OF EMPLOYEES

Graham Lavin and John P Spillane[1]

School of Engineering, University of Limerick, Castletroy, Limerick, V94 PH61, Ireland

Irish construction professionals have long been acknowledged for working a traditional five-day work pattern, with inflexible work hours, while commuting extended hours, to and from work each day. The aim of this study is to investigate the compressed work week as an alternative work schedule, increasing hours worked per day and reducing working days, while still achieving the standard number of hours worked, under the lens of the perceived impact on health and wellbeing of these professionals. To ascertain the impact, six in-depth semi-structured interviews are conducted with construction professionals in the Irish construction industry. The results are transcribed, coded and themes highlighted under two overarching concepts; positive and negative impact of the introduction of compressed working week on health and wellbeing. The results, although based on the perceptions of a small sample, indicate potential positive impact on health and wellbeing include; more time with family/friends, more time for and better-quality rest and recuperation, less commuting time, increased leisure time and, longer weekends. However, several negative impacts on health and wellbeing emerged; potential exhaustion, particularly those with physically strenuous tasks, poor diet due to longer time on-site, increased difficulty working in winter months (cold/daylight), exhaustion post commute home after a long twelve-hour day and, not seeing family/friends due to late arrival home. Subsequently, the findings indicate a divergence of opinion with those interviewed, based on two core factors; the age of the interviewee and their profession; that is, if they experienced physical exertion, carrying out their daily tasks. Those of a younger age showed a preference for the introduction of a compressed working week, while those of an older age, and, carrying our physical tasks, were far less enthusiastic on the adoption of the revised working week. The results indicate that, although from a small sample size, the introduction of a compressed working week has the potential to increase employee well-being; however, due to the increased working day, the adverse effects of diet and exhaustion, both on-site but also when commuting home, must also be given due consideration.

Keywords: compressed working week, four-day week, health and wellbeing

INTRODUCTION

The Irish construction industry generally abides by a traditional work pattern. Construction professionals have long been acknowledged of working long and inflexible work hours, while commuting extended hours to and from work each day (Lingard, *et al.,* 2007). The compressed work week is an alternative work schedule,

[1] john.spillane@ul.ie

Lavin G and Spillane, J P (2019) Implementing a Compressed Working Week in the Irish Construction Industry: Perceived Impact on Health and Wellbeing of Employees *In:* Gorse, C and Neilson, C J (Eds) *Proceedings of the 35th Annual ARCOM Conference,* 2-4 September 2019, Leeds, UK, Association of Researchers in Construction Management, 507-516.

increasing hours worked per day and reducing working days while still achieving the standard number of weekly hours required (Ronen and Primps 1981). It is generally perceived that the work life of construction professionals is rather taxing on the body, both mentally and physically, with fatigue being one of the leading human factors, contributing to accidents on site (Adi and Ratnawinanda 2017; Lingard and Turner 2017). With the current prosperity in the construction sector, more labour-intensive work has become available. It is important to continue to monitor individual's health and wellbeing while working the long, taxing work weeks. A compressed working week has been implemented in many industrial sectors in Ireland and worldwide. Its aim is to increase the number of days away from work while still achieving its desired results. Ideally, employees will spend time resting and recuperating while spending time with family, in the hopes that they will be fresh and motivated once returning to work (Lingard, *et al.,* 2007). Extensive work has been put into demonstrating how compressed working weeks can impact the health of night shift employees. However, there is a gap in literature regarding standard working days and its impact. Based on this, the aim of this paper is to investigate the impact of a four-day work week on the health and wellbeing of construction professionals in Ireland. In doing so, this will provide an opportunity to gain insight into construction professionals current lifestyle and their perceptions on reducing the working week, detailing past experiences. Subsequently, it is possible to highlight both the benefits and disadvantages, from a safety, health and wellbeing perspective, of implementing a compressed working week in respect to health and wellbeing of construction professionals in Ireland.

This study will focus on a four-day 40-hour work week, in where the days worked will be Monday through Thursday. The general health of employees, primarily their self-reported physical health will be investigated. Construction professional's current lifestyle and lifestyle under the compressed working week will be examined. In addition, knock on effects of lifestyle will be surveyed, for example, diet, activity level, smoking, stress, alcohol and social factors. Construction professionals of different ages will be examined along with daily routines such as travelling, and leisure activities are also included. Productivity or output on the compressed working week will not be investigated or considered, nor will the financial impacts - the focus is on health and wellbeing. To achieve the aim, a qualitative approach is adopted, to gain the viewpoints of varying industry professionals. The findings will be analysed and coded, where theory generation via thematic coding will result in the identification of patterns in the results. Eight in-depth semi-structured interviews are carried out with construction professionals from the Irish construction industry. The results, although only based on a preliminary study, will provide the basis for the justification for further investigation on the potential introduction of a compressed working week within some sectors of the Irish construction industry.

COMPRESSED WORKING WEEK: A LITERATURE REVIEW

The compressed working week in the construction industry is an area containing limited research. However, there has been work done on the compressed working week in similar labour-intensive industries, with the emphasis being on productivity rather than general wellbeing. In this context, shift work is generally investigated more extensively when compared with that of traditional or standard work schedules. Kattenbach *et al.,* (2010) found that time restriction or the compressed work week is related to exhaustion and fatigue; however, the subsequent extra day off was not examined to investigate its implication for added rest and/or leisure time. The levels

of exhaustion were also subjective, and therefore, could not be accurately analysed. Furthermore, the standard eight-hour construction working day has generally been associated with exhaustion regardless (Hartmann and Fleischer 2005; Fang *et al.,* 2015). In a study by Milia (1998), it concluded that sleep was not significantly altered, when changing from an eight to a twelve-hour shift. Sleep on a twelve-hour shift initially increased by 0.51 hours, but returned to the baseline, once adapted. However, the study fails to consider the health implications for each work system, only focusing on perceptions and preferences and sleep duration rather than quality.

Bambra *et al.,* (2008) explored the effects of compressed working week interventions on the self-reported health and work-life balance of shift workers. The results suggest that there were little adverse health impacts on implementing the compressed working week. In addition, the study suggests that there is a relationship between improved work-life balance and improved health. However, the results were viewed to be somewhat inconclusive, where it suggested that more precise studies that measured objective health are needed. The study was also carried out on night shift workers, which may produce different results, as studies have previously showed the negative health impacts related to working night shifts (Costa 1996), but with no link to that of the current proposed compressed working week. Working longer hours may not directly impact physical health. However, it may have subsidiary effect, such as, poor diet, increased smoking and, alcohol consumption (Maruyama and Morimoto 1996). Furthermore, the study suggest that the increased work hours may result in higher stress levels and reduced quality of life in general. This study considers a five-day week, with in excess of ten-hour work days and therefore, does not consider the extra day off associated with the proposed compressed work week. Sparks *et al.,* (1997) suggested that there is a link between long work hours and poor health. The study focuses on overall weekly hours worked, and not on the distribution of work hours throughout the week, and more importantly, the resultant impacts. Therefore, the results are inconclusive, requiring further research.

The study also suggests that specific occupations must be looked at as different workloads are expected in different occupations. Cunningham (1989) examined the negative impacts of shift work, paying attention to the psychological and behavioural effects of coal miners working on a compressed shift schedule. By measuring blood pressure, respiratory functioning, reaction time, vigilance and auditory functioning, the study advocates that there is no negative impact on health, yet, there was an increase in subjective fatigue and tiredness. However, the results ignore social factors, such as alcohol, being an inhibiting factor. Much of the literature regarding the compressed work week fails to consider the impact on employees of different age groups. Tellier (1974) explores the effects of the four-day work week on the elderly. This system was generally preferred due to the extra day off leading to increased leisure time. However, fatigue was once again problematic. With that, the sample size was rather small. The introduction of a twelve-hour shift across fewer working days, led to the improvement in gastrointestinal disorders, such as heartburn, acid stomach and diarrhoea (Johnson and Sharit 2001). It is thought that the reduction of days worked enabled those to eat on a more traditional basis and therefore, eat healthier. The reduction in stress associated with less work days could also alleviate these disorders (Lees and Laundry 1989). In line with this, long commuting times were associated with poor sleep quality, exhaustion and low self-rated health, while it was suggested that mental health was not significantly associated with commuting (Hannson *et al.,* 2011). The cross-sectional study makes it hard to conclusively

attribute these health impacts solely to commuting, as other external factors are certain to contribute. The nature of the commute must also be carefully examined. It is important to not only consider the commute distance, but also to look at duration, traffic, time of commute, and nature of the roads and surroundings (Milia 2006). Lingard *et al.,* (2007) advocates that the work life balance of construction personnel is an important issue which directly correlates to occupational health, in which work-life conflict may contribute to burnout, mental health issues and substance abuse. The study found that a compressed work week was successful in improving the work-life balance of employees. It is worth noting that this study focuses on moving from a six to a five-day week. Furthermore, the main emphasis of the study is on performance and productivity rather than health and wellbeing, which was largely overlooked. A study by Martens *et al.,* (1999) focused on the relationship between flexible work schedules and general health and wellbeing. The study concludes that those working compressed work schedules were subject to more physical health problems, reduced sleep quality, and poorer general well-being, compared to those operating on a more traditional work schedule. The results from this study were gathered by patients communicating their health problems with their family physician. Therefore, results may be inconclusive as there may have been many factors contributing to the patient's illness, with their work schedule being just one of these factors. Brown *et al.,* (2010) stated that compressing the work schedule, aided in the ability to recover from the long and taxing work week, subsequently improved their work-life balance and general wellbeing. The longer break at weekends enabled individuals to engage in more favourable activities, which led to feeling refreshed and ready to return to work the following week. This study was conducted with professionals in the Australian construction industry, who were subject to a previous 6-day week; therefore, the findings may be difficult to apply in the Irish context. From analysing the literature, aspects relating to a compressed working week are evident; however, they focus on other industries and/or professions. The majority focus on extended work hours, also considering shift or night working, but not a reduction in the number of days work - a gap in knowledge that this paper aims to address. The current body of research lacks investigation into the application of a compressed working week in construction, and more so, in the Irish construction industry; hence the need for further investigation.

RESEARCH DESIGN

To explore the impact to health and wellbeing of a compressed working week in the Irish construction industry, a qualitative approach is adopted, founded on eight semi-structured interviews. In line with Lingard, *et al.,* (2008) and O'Riain, *et al.,* (2018), semi-structured interviews were applied, due to the flexibility of response obtained from the interviewees, as it fosters a conversational nature. The interviews are conducted in an open-ended format, to generate an in-depth discussion on themes or prominent issues. All pre-determined questions or relevant probes are tabled in the same style, order and responses noted accordingly, to improve replicability of result. The interviews are focused around six key themes, all of which were prominent and emanated from the following literature;

- Sleep (Milia 1998; Milia 2006)
- Recovery and Leisure (Maruyama and Morimoto 1996; Brown *et al.,* 2010; O'Riain *et al.,* 2018)
- Work life Balance (Lingard *et al.,* 2007; Bambra *et al.,* 2008)
- Burnout and Fatigue (Kattenbach *et al.,* 2010; Adi and Ratnawinanda 2017)

- Travel Impacts (Milia 2006; Hannson *et al.,* 2011; O'Riain *et al.,* 2018)
- Knock on effects (Ronen and Primps 1981; Maruyama and Morimoto 1996; Lingard *et al.,* 2008)

In total, eight interviews were conducted with construction professionals from the Irish construction industry. Participants were selected based on criterion selection; experience working within the Irish construction industry, expertise (manager/trade) and perspectives. Of the eight interviewees, five were male, three, female. Interviewees ranged in age from early twenties to late fifties. Occupations include General Operative (#1), Apprentice Electrician (#2), Quantity Surveyor (#3), Site Engineer (#4), Project Manager (#5), Construction Manager (#6), Architect (#7), and a Block Layer (8). Average commute time to/from work each day was just over 1 hour each way. Finally, all interviewees currently work a standard five-day, 40-hour week.

Interviews were conducted both in person, but also using voice-over internet protocol, where the interviewee was located considerable distance from the interviewer and/or at the request of the interviewee. The interviewees were requested to provide their opinion or experience of the possible health and wellbeing benefits and/or detriments associated with working a standard five-day 40-hour week, compared to that of the proposed compressed four-day 40-hour week, detailing their current lifestyle. Emphasis was placed on their opinions of where such an approach was adopted, how they perceived would be the impact on them, or others involved in the industry, in terms of mental health, physical health and general wellbeing. Given the similar nature of each interview, where the interviewees were given identical instructions, in the same order, and with the equivalent meaning or intent, data is therefore comparable. Data was extracted, by carefully studying the completed interviews scripts and subsequently coding the responses based on the themes identified above.

RESULTS

The combined list of factors from each interview are documented, where a positive symbol (+) denotes a positive factor, while a negative symbol (-), a negative factor. Each factor identified is grouped, based on the themes identified above. In total, six themes emerged, with a total of 42 factors (Table 1).

DISCUSSION

Theme 1 - Sleep

The first and most prominent theme that emerged from the interviews was the impact on sleep. Of the interviewees, half indicated that sleep would not be greatly affected by compressing the work schedule. With three expressing that people would be able to adjust to the new sleep routine. These results compliment the work of Milia (1998), where she states that "no significant differences were found for total sleep times between the systems." Furthermore, half believe that the extra day off leading into the weekend could be used as a means of catching up on sleep, that may have been lost through incorporation of the compressed schedule. In contrast, just 2 participants suggested that the compressed working week would have a significant negative impact on the sleep of those involved, which may in turn lead to poor health. Moreover, 3 voiced concern as to how the new schedule may impair their sleep routine, such that, it would be more difficult to sleep Sunday and rise on the Monday.

Table 1: Themes and associated factors

(+) Extra day off would benefit trades	4
(+) More time off to deal with personal issues (Dentist, Doctor, etc.)	4
(+) More active over the weekend due to the extra time available	2
(+) More time to yourself and to improve your mental wellbeing	3
(-) No leisure time mid-week	2; 4; 5; 6; 7; 8
(-) Less likely to spend the extra time resting	1; 2; 4; 5; 7; 8
(-) Too tired at weekends to do anything	1
Work Life Balance	Interviewee #
(+) Happier with less days at work	1; 2; 4; 5; 7; 8
(+) Extra days with family including to go away at weekends	1; 2; 8
(+) Better quality of life	1
(-) Less time with family during the week	3; 6; 7
(-) More time at home which may not be good	2
Burnout and Fatigue	Interviewee #
(+) Body would adjust to longer days	1; 2; 5; 6; 7
(+) Longer days would not be issue with fatigue	4
(-) Increased strain on the body physically	1;2;3;5;6;7;8
(-) More accidents on-site	2; 3; 5; 6; 8
(-) More likely to become run down	7
(-) Longer days problematic for older individuals	4
(-) Longer days would be mentally exhausting	4
Travel	Interviewee #
(+) Less stress travelling outside rush hour	3; 4; 5
(+) No impact on commute where close to site	1; 7
(+) Less travel days would be good mentally	3
(+) No impact on safety while driving	1
(-) More dangerous commute due to being tired and/or rushing home	2;3;4;5;6;7;8
Knock-on Effects	Interviewee #
(+) Peoples habits will continue as before (diet, smoking, etc.)	3
(+) Extra day of healthier eating	4; 5; 8
(-) Increased alcohol/tobacco consumption	1;2;3;4;5;6;7;8
(-) Less substantial and healthy meals; more snacking and fast food	1; 2; 8
(-) More painkillers	8
Sleep	Interviewee #
(+) Not much impact on sleep overall	1; 3; 4; 5
(+) More sleep on days off	1; 3; 4; 7
(+) Would be getting up early anyway	1
(-) Extra day off would ruin sleep pattern	1
(-) Harder to sleep on a Sunday night	2; 8
(-) Easier to fall asleep during the week	7
Recovery and Leisure	Interviewee #
(+) More time to rest and recuperate	2; 3; 5; 6; 7
(+) More breaks beneficial	2; 5; 8
(+) More free time for leisure	3; 6; 8
(-) May under eat on longer days	2

With that, the extra day off left individuals more replenished and motivated for the upcoming week ahead. However, 6 participants raised concerns regarding the inability to engage in any leisure activities during the week, due to the lack of available time in the evenings, arising from the longer days. This was especially problematic for those who engaged in activities with specific time restraints, such as team sports, gym classes, and other schedule-based activities. Additionally, of those interviewed, 5 voiced apprehension as to how the extra day off would be spent. The overriding feeling was that the additional day off may not be spent resting and recuperating, but rather spent doing other and perhaps similar, taxing work.

Theme 3 - Work Life Balance

One aspect noted by 3 interviewees, believe that the extra day off at the weekends would be beneficial, given that the extra free time and time with family may alleviate stress. Over a third noted that the extra day would provide an opportunity to spend extra time with family and/or friends, or simply as an extra day away from the workplace, which would further aid mental wellbeing; a view shared by 6 of the candidates. Likewise, Lingard *et al.,* (2007) found that the increased personal and family time linked to the compressed schedule was able to improve "psychological wellbeing". However, 3 interviewees believe that the longer days would limit time they get to spend with family and friends, which they deem to be very upsetting.

Theme 4 - Burnout and Fatigue

Of those interviewed, all but one expressed concern of the physical toll, the extra daily hours would have on the body; particularly for those undertaking physical work on-site. Given that the standard work week is already labour intensive and physically demanding for trades, the above-mentioned interviewees believe the extra hours work may be detrimental to health and wellbeing. Previous literature is consistent with this, in that, the numbers of hours worked each week is related to burnout, and in particular, emotional exhaustion (Lingard and Francis 2005; Lingard 2012). Given the possible knock one effects, such as fatigue and tiredness, 5 interviewees suggest that there would be more accidents, incidents and near misses on-site, due to decreased alertness and concentration. Furthermore 2 participants voiced concerns to working within a system which may change from daylight to darkness or vice-versa. Tellier (1974) found that the 4-day work week may be problematic for older individuals, stating that the extra physical toll may be harmful for those involved. However, only one participant raised concerns regarding this matter. Nevertheless, despite the fear relating to the physical impact on the body, 5 participants echoed that eventually individuals would adjust to the added work load undertaken each day, provided that the schedule is properly adhered to and adequate rest is taken during days off.

Theme 5 - Travel

The aspect of travel to/from work was also a prominent concept discussed. 37.5% were of the viewpoint that one less day of travelling each week, would be beneficial psychologically, given that people are often times commuting long distances each day in often uncomfortable and stressful traffic congestion. Furthermore, the opportunity to possibly travel outside of "peak hours" (provided the schedules enable this) would be more relaxing and preferable. In support of this, Hannson *et al.,* (2011) found links between extended travel time and poor health; thus, suggestion further, that reduced

travel time be considered for the betterment of health and wellbeing of those concerned. Interestingly, 87.5% felt that the longer hours each day and the subsequent fatigue and tiredness associated, may result in more dangerous journeys home after work, particularly towards the latter end of the working week. 33% of the afore mentioned expressed concerns for those travelling longer distances, as they believe they may be more susceptible to crashes/accidents. Milia's (2006) study show that driving becomes more detrimental for those working extended hours (10 to 12-hour days). In addition, those who need to rise earlier to fulfil the work commitments, are at a greater risk of being involved in road accidents (Folkard And Barton, 1993).

Theme 6 - Knock-on Effects

All participants to the study shared the view that, for certain people, depending on their situation and preferences, the extra day off could result in greater alcohol consumption. However, there is limited research regarding the compressed working week and alcohol consumption; however, research indicating that long working hours are directly correlated to increased alcohol consumption (Spurgeon *et al.,* 1997). Additionally, increased smoking due to the longer work days was a viewpoint consistent with 75% of those interviewed. The consensus was that the longer work hours and the possible stress associated, would result in the increased consumption of cigarettes. Johnson and Sharit (2001) found that moving from an eight-hour to a twelve-hour shift, led to the reduction in gastrointestinal disorders, due to the ability to eat on a more traditional, and therefore, healthier basis. However, the findings from this study do not coincide with this. Half of those interviewed believe that the extra hours each day may result in poorer eating habits, in the form of; undereating, increased snacking, and less substantial meals. Of interest, only 12.5% of the interviewees agreed with the work of Johnson and Sharit (2001). Yet, 37.5% argued that it is also possible that people's habits will continue as before.

CONCLUSIONS

With health and wellbeing of those in the construction industry continuing to come into focus, this paper considers the introduction of a compressed working week, as one of many solutions. The results suggest that the positive impacts on health and wellbeing include; more time away from the workplace, more time for and better-quality rest and recuperation, less commuting time, increased leisure time and, more time with family and friends on days off. However, several negative impacts on health and wellbeing emerge; potential exhaustion, particularly those with physically strenuous tasks, poor diet due to longer time on-site, increased alcohol consumption on weekends, increased difficulty working in winter months (cold/daylight), exhaustion post-commute home after a long day and, the stresses associated with not seeing family/friends, due to late arrival home. The findings indicate that there are many advantages and disadvantages associated with adopting the compressed working week; however, it is unclear as to the degree to which the proposed system may improve/dis-improve the health and wellbeing of those involved. Interestingly, there was little differences in the respondents concerns and comments, regardless of their profession, such as physical concerns of those within a trade background; Block Layer (#8), versus more senior managerial positions; Project Manager (#5), Construction Manager (#6). However, there were differences in opinion based on age of the respondents, with those of a younger age, reflecting an increased desire for the introduction of a compressed working week, while also downplaying concerns relating to additional working hours mid-week. Although the findings are from a

small sample size, those who participated are from a wide array of professional backgrounds, with varying levels of experience, including gaining the viewpoints from both male and female respondents, to mitigate this issue, where possible. Further studies focusing on the objective health and wellbeing of construction personnel is required, including the perceptions of a more diverse and wider array of participants, in addition to a potential qualitative survey, to gauge a wider appreciation of the topic. Additional in-depth interviews and subsequent focus groups would also be of value, particularly given that the findings are based on the perceptions of just six individuals, to further reinforce the legitimacy of the findings. However, early findings support further investigation, as there are clear benefits to improving the health and wellbeing of those whom work in, what is widely considered, a difficult profession.

REFERENCES

Adi, T J W and Ratnawinanda, L A (2017) Construction worker fatigue prediction model based on system dynamic, *In*: *The 6th International Conference of Euro Asia Civil Engineering Forum*, 22-25 August, Seoul, South Korea

Bambra, C, Whitehead, M, Sowden, A, Akers, J and Petticrew, M (2008) 'A hard day's night?' The effects of compressed working week interventions on the health and work life balance of shift workers: A systematic review, *Journal of Epidemiology and Community Health*, 62(**9**), 764-777.

Brown, K, Barth, S, Bradley, L M and Lingard, H (2009) What about me? Avoiding fatigue and gaining personal time in the work to leisure transition in work-life balance initiatives, *In*: N Beaumont (Ed.) *23rd Annual Australia and New Zealand Academy of Management Conference (ANZAM 2009)*, 1-4 December, Melbourne, Australia

Costa, G (1996) The impact of shift/night work on health, *Applied Ergonomics*, 27(**1**), 9-16.

Cunningham, J (1989) A Compressed shift schedule: dealing with some of the problems of shift-work, *Journal of Organizational Behaviour*, 10(**3**), 231-245.

Fang, D, Jiang, Z, Zhang, M and Wang, H (2015) An experimental method to study the effect of fatigue on construction workers' safety performance, *Safety Science*, 73(**1**), 80-91.

Folkard, S and Barton, J (1993) Does the 'forbidden zone' for sleep onset influence morning shift sleep duration? *Ergonomics*, 36(**1-3**), 85-91.

Hannson, E, Mattisson, K, Björk, J, Östergren, P-O and Jakobsson, K (2011) Relationship between commuting and health outcomes in a cross-sectional population survey in southern Sweden, *BMC Public Health*, 11(**834**), 1.

Hartmann, B and Fleischer, A (2005) Physical load exposure at construction sites, *Scandinavian Journal of Work Environment and Health*, 31(**2**), 88-95.

Johnson, M D and Sharit, J (2001) Impact of a change from an 8-h to a 12-h shift schedule on workers and occupational rates, *International Journal of Industrial Ergonomics*, 27(**5**), 303-319.

Kattenbach, R, Demerouti, E and Nachreiner, F (2010) Flexible working times: Effects on employee's exhaustion, work-nonwork conflict and job performance, *Career Development International*, 15(**3**), 279-295.

Lees, R and Laundry, B (1989) Comparison of reported workplace morbidity in 8-hour and 12-hour shifts in one plant, *Occupational Medicine*, 39(**3**), 81-84.

Lingard, H, Brown, K, Bradley, L, Bailey, C and Townsend, K (2007) Improving Employee's Work-Life balance in the construction industry: Project alliance case study, *Journal of Construction Engineering and Management*, 133(**10**), 808-814.

Lingard, H C, Townsend, K, Bradley, L and Brown, K (2008) Alternative work schedule interventions in the Australian Construction industry: A comparative case study analysis, *Construction Management and Economics*, 26(**10**), 1101-1112.

Lingard, H and Francis, V (2005) Does work-family conflict mediate the relationship between job schedule demands and burnout in male construction professionals and managers? *Construction Management and Economics*, 23(**7**), 733-745.

Lingard, H (2012) Occupational health, safety and workers' wellbeing. In: A Dainty and M Loosemore (Eds.) *Human Resource Management in Construction: Critical Perspectives*. London: Routledge, 130-162.

Lingard, H and Turner, M (2017) Promoting Construction Workers' health: A multi-level system perspective, *Construction Management and Economics*, 35(**5**), 239-253.

Martens, M, Nijhuis, F, Van Boxtel, M and Knottnerus, J (1999) Flexible work schedules and mental and physical health: A study of a working population with non-traditional working hours, *Journal of Organizational Behaviour*, 20(**1**), 35-46.

Maruyama, S and Morimoto, K (1996) Effects of long workhours on life-style, stress and quality of life among intermediate Japanese managers, *Scandinavian Journal of Work, Environment and Health*, 22(**5**), 353-359.

Milia, L D (2006) Shift work, sleepiness and long-distance driving, *Transportation Research Part F: Traffic Psychology and Behaviour*, 9(**4**), 278-285.

Milia, L D (1998) A longitudinal study of the compressed workweek: Comparing sleep on a weekly rotating 8 h system to a faster rotating 12 h system, *International Journal of Industrial Ergonomics*, 21(**3-4**), 199-207.

O'Riain, E, Spillane, J and Sherratt, F (2018) Healthy, Happy Workers? The Consequences of Commuting Between Northern Ireland and Great Britain. *In:* Gorse, C and Neilson, C J (Eds.), *Proceedings of the 34th Annual ARCOM Conference*, 3-5 September 2018, Queen's University, Belfast, UK. Association of Researchers in Construction Management, 311–320.

Ronen, S and Primps, S B (1981) The compressed work week as organizational change: Behavioural and attitudinal outcomes, *Academy of Management Review*, 6(**1**), 61-74.

Sparks, K, Cooper, C, Yitzhak, F and Shirom, A (1997) The effects of hours of work on health: A meta-analytic review, *Journal of Occupational and Organizational Psychology*, 70(**4**), 391-408.

Spurgeon, A, Harrington, M J and Cooper, C L (1997) Health and safety problems associated with long working hours: A review of the current position, *Occupational and Environmental Medicine,* 54(**6**), 367-375.

Tellier, R D (1974) The four-day workweek and the elderly: A cross-sectional study, *Journal of Gerontology*, 29(**4**), 430-433.

PRACTISING OCCUPATIONAL HEALTH AND SAFETY USING SOCIAL PRACTICE THEORY

Ani Raiden[1] and Emmanuel Aboagye-Nimo[2]

[1] *Nottingham Business School, Nottingham Trent University, 50 Shakespeare Street, Nottingham, NG1 4FQ, UK*

[2] *School of Architecture Design and the Built Environment, Nottingham Trent University, 50 Shakespeare Street, Nottingham, NG1 4FQ, UK*

Occupational health and safety literature embodies two worlds: one that takes a hard, top-down approach with a view that legislation and organisational policy and procedures are essential to achieving an environment that mitigates risks to workers' health and/ or safety. The other takes a social constructionist view and places the worker at the heart of mobilising health and safety at work. Despite advancements in research and practice in both spaces, accidents still happen at work and worker health and well-being feature at the forefront of management agenda. We employ social practice theory to bring together the discourse of the two worlds in occupational health and safety research and practice. Social practice theory offers a framework for analysis which attempts to synthesise the structural focus of systems, such as legislative frameworks and organisational policy and procedures on occupational health and safety, and the processual and cultural, the socially constructed, approaches. Through illustrative data and analysis, we argue that such integration holds the key to extending work in this important area. Our discussion shows how individuals' attitudes, behaviours and choices are connected with occupational health and safety practice, and also, more importantly, we identify how occupational health and safety practices form, how they are reproduced, maintained, stabilised, and challenged through the key themes that emerge from our empirical data.

Keywords: social practice theory, occupational H&S, discourse, safety climate

INTRODUCTION

Occupational health and safety (OHS) literature embodies two worlds: one that takes a hard, top-down approach with a view that legislation and organisational policy and procedures are essential to achieving an environment that mitigates risks to workers' health and/ or safety. This perspective is aligned with rational management and has tended to dominate research and practice in and about organisations, work, workers and the organisation-work-worker relationships, including literature on occupational health and safety. The other takes a social constructionist view and places the worker at the heart of mobilising health and safety at work. Understanding the impact of individual and group characteristics (such as worker behaviour, perception, and safety climate) on occupational health and safety are at the heart of this perspective. As workers are definitive key stakeholders in occupational health and safety, interest and research in this space is growing. However, despite advancements in research and

[1] ani.raiden@ntu.ac.uk

Raidén, A and Aboagye-Nimo, E (2019) Practising Occupational Health and Safety Using Social Practice Theory *In:* Gorse, C and Neilson, C J (Eds) *Proceedings of the 35th Annual ARCOM Conference,* 2-4 September 2019, Leeds, UK, Association of Researchers in Construction Management, 517-526.

practice in both spaces, accidents still happen at work and worker well-being features at the forefront of management agenda.

We employ social practice theory to bring together the discourse of the two worlds in occupational health and safety research and practice. Social practice theory offers a framework for analysis which attempts to synthesise the structural focus of systems, such as legislative frameworks and organisational policy and procedures, and the processual and cultural, the socially constructed, approaches.

The central research question in this paper is: *How do workers perceive and practice occupational health and safety on construction sites operated by micro firms?* Our point of departure is that social practice theory offers an integrative and holistic framework for analysis of such subjective and complex phenomena. Consequently, we first develop a critical review of literature on occupational health and safety. We then introduce social practice theory and develop an analytical framework. An outline of the research method and approach follows, before analysis of our illustrative empirical data and discussion.

Occupational health and safety

Rhetoric, The best practice literature on occupational health and safety
Much of the best practice literature on occupational health and safety takes a top down, central policy driven approach. For example, Boardman and Lyon (2006) specify a best practice framework for the governance of occupational health and safety (OHS) in companies (see Figure 1), which emphasises managerial activity and organisational structures and systems as the primary agents. At the same time, their research identifies *"an urgent need for improved advice and guidance (and even support) from the regulators to enable directors to take better control of OHS within their organisations"* (p. 4). Such a focus on managerial activity and director responsibility, together with a desire for more control, undermines one of the five key action points earlier work supports: *"To engage the workforce in H&S matters"* (page 1).

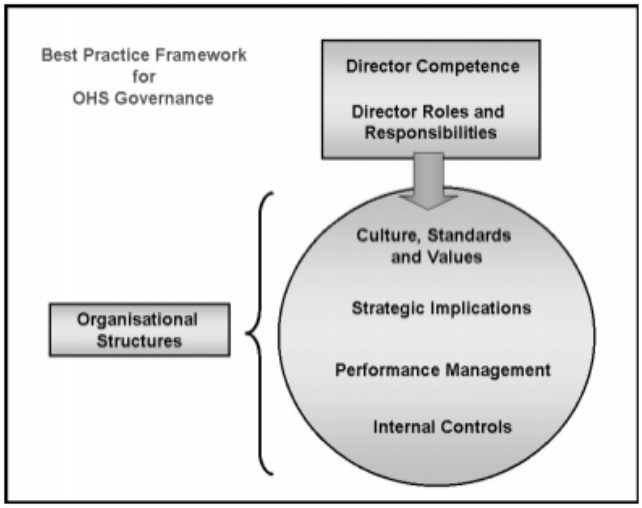


Figure 1: Best practice framework for occupational health and safety governance (source: Boardman and Lyon, 2006: 2)

The European Agency for Safety and Health at Work (2019) similarly place senior managers at the heart of managing occupational health and safety *"Strong, effective*

and visible leadership is vital to good workplace safety and health" but with worker participation:

> One of the keys to good OSH leadership is getting workers involved. Employers have a legal duty to consult employees on safety and health issues. But there are benefits to going beyond the minimum requirements. OSH management will be more likely to succeed if it encourages the active participation of workers and sets up a dialogue between employees and management.

Emphasis still lies in management action; consultation driven by an organisational agenda. This carries forward to small and micro firms too - the HSE (2019) sets out the responsibilities for ensuring that they and any subcontractors have *"the skills, knowledge, experience and training to carry out the work in a way that secures health and safety, or is in the process of obtaining them"*.

Perception

Research from sociology and psychology offers alternative perspectives for approaching and developing the occupational health and safety discourse. For example, Simpson's (1996) work on the cautious, confident and neutral cognitive frameworks regarding safety focuses on perceptions [and thus behaviour] as *"'intersubjective' - products of social construction, collective agreement, and socialization"* (see also Sherratt *et al.,* 2013: 623; Andersen *et al.,* 2015 for discussion in the context of construction). It is agreed and well documented that work on a construction site is dangerous, hence, arguably, the cautious framework presents as the most appropriate choice in this environment. Certainly, safety policies tend to highlight danger and encourage the use of the cautious framework. While this may not apply universally, e.g. some may perceive construction work through the neutral framework, it is possible that the confident framework presents an inappropriate choice given the long history of workplace incidents, accidents and fatalities.

Violations of the framework that is assumed appropriate in a given context deviate from the socially appropriate use of such a framework and introduce an element of surprise and uncertainty (Simpson, 1996: 557) and thus may generate perceptions of power and control in the face of organisational policy. For example, a macho showcase of the confident framework on a construction site where many hazards are present may be used to demonstrate bravery and/ or superior knowledge or be enacted as a symbol of defiance.

Critical view - Occupational health and safety practice

Contrary to the managerialist rhetoric, Esmaeili and Hallowell (2012) show that employee involvement has received increasing attention in organisational practice over the past decade as an innovative way to enhance performance on occupational health and safety. Sherratt *et al.,* (2013) also note a change in safety management strategies. They show paradoxical discourses: one of enforcement of safety, another of engagement.

Hung *et al.,* (2011) bring in critical perspective, specifically regarding practice vs rhetoric: SMEs say they desire safe and healthy working environment and wish to avoid accidents, but their behaviour is often risky. This raises questions about the application of empowering strategies. Sherratt *et al.,* (2013: 631) support this with research about violation of safety rules, bending and breaking of rules and workers absolving themselves of responsibility for safety. Violation is expected and a matter of course on site (ibid.).

SOCIAL PRACTICE THEORY

Theories of social practice have formed a conceptual alternative to previously polarised schools of thought, such as Rational Choice Theory and norm-oriented theory of action, with an interest in the 'everyday' and 'life-world' (Reckwitz, 2002). Drawing on the philosophical principles of phenomenology, social practice theory offers a framework for explaining and understanding actions and knowledge which enable and constrain agents in interpreting the world and behaving in corresponding ways. Social order is embedded in collective cognitive and symbolic structures, in a 'shared knowledge' which enables a socially shared way of attributing meaning to the world (ibid: 246).

In our paper 'practices' refer to occupational health and safety as *"a routinised type of behaviour which consists of several elements, interconnected to one other: forms of bodily activities, forms of mental activities, 'things' and their use, a background knowledge in the form of understanding, know-how, states of emotion and motivational knowledge"* after Reckwitz (2002: 249). This approach is a good fit to our research and empirical data; hence we have chosen it from within the many options available within practice-based research (see for example Schatzki, 2001; Shove and Pantzar, 2005). Agents are regarded as carriers of the routinised type of behaviour; *"skilled agents who actively negotiate and perform a wide range of practices"* (Hargreaves, 2011: 83). Social practice theory 'decentres' mind, text and conversations, and shifts *"doing"* (ibid), bodily movements, things, practical knowledge and routine to the centre (Reckwitz, 2002: 259). Social practice theory in this view raises a series of different questions about occupational health and safety. The focus is not only on individual's attitudes, behaviours and choices, but also, and more importantly, on how practices form, how they are reproduced, maintained, stabilised, challenged, and maybe killed-off (Hargreaves, 2011).

RESEARCH METHOD AND APPROACH

The primary source of empirical data relevant to this research paper is a set of semi-structured interviews carried out on construction sites in the East Midlands (n=17) and South East (n=12) in the UK. We utilise two specific transcripts from within this larger data set to explore the connections and synthesis of the two worlds in OHS using social practice theory. One transcript is an interview with two subcontractors who work on a larger construction site: Dave [R1] and Lee [R2] are employed by a micro firm and have been working in the industry for 40 years. The other transcript is from an interview with Anthony [R3], an owner manager of a small firm who actively engages in construction work as well as site management and supervision. These are not the real names of the research participants, and we will not disclose the site locations. Pseudonyms have been assigned to protect the interviewees' identity and anonymity, and to ensure the confidentiality of their responses.

The central concepts and our research approach align ontologically as a course of interaction which arises out of shared perspectives or perspectives that are negotiated (after Blumer, 1969). In other words, we believe that individuals do not operate in isolation, but may make decisions based on the values of others. Specifically, we understand that occupational health and safety practices are influenced by a wide range of social actors, including, for example, individual perceptions, managers' influence, training, and communications with colleagues. In turn, the social actors' knowledge relating to occupational health and safety is also affected by the relationship amongst workers and the extent to which the environment at work is

supportive (Laukkanen, 1999). Practice-based perspective holds that human activities are inseparable; knowledge can be developed through processes such as socialisation, observation and practice (Orlikowski, 2002). Within such a philosophy, the aim is to grasp the subjective meaning of social action (Reckwitz, 2002; Bryman and Bell, 2007: 19). We have adopted an empathetic stance (Saunders *et al.,* 2009: 116) in order to enter the world of the research subjects so as to gain an understanding of their world from their point of view (Pink *et al.,* 2010; Saunders *et al.,* 2009).

Illustrative Data and Analysis

A wide range of important themes emerged from the analysis of the two transcripts, including learning, perception and knowledge transfer; interpersonal relationships; cautious mindset and co-creating occupational health and safety; organisational hierarchy; rules; and barriers.

Our point of departure in the illustrative data and analysis is a quote from Anthony:

> …it's really the practice on site that matters. [R3]

This presents us with the ultimate lead into applying social practice theory as a lens to first showcase examples of *forms of bodily activities, forms of mental activities, 'things' and their use, a background knowledge in the form of understanding, know-how, states of emotion and motivational knowledge* (after Reckwitz, 2002) and then locate the key themes within these practices, and pull together the two worlds in occupational health and safety.

Learning, perceptions and knowledge transfer

Connections between place (off site vs on site), theory vs practice, and feasibility of learning transfer were important topics for discussion for the two workers we interviewed:

> …they've been taught something in the classroom that technically is right, but when you get onsite sometimes it's not practical. You can learn lots of things in the classroom, but when you go on-site sometimes it's impossible to do and they might say to you, "Yes, but we didn't learn that, you're meant to do this and that" and you say, "Well, you can't do it like that, because you just can't physically do it." That's where you get a lot of… Especially, like office material, where they've got a degree in site management and things like that, they might be very well qualified on the theory and everything else, but when you go out on-site you need to have the practical skills. [R1]

The owner manager of a small firm expressed similar concerns with regards to training, and stressed practical showcasing of learning and skills and the ability to transfer knowledge into practice over training:

> It's more about competence… much less interested in training, and we've taken that philosophy on board… ongoing proof of competence, and adhering to the correct methods of working… because you can have people turn up to be trained, and they sit in a room… I consider it far more important to see whether they've actually learnt what they've been shown. [R3]

Deep rooted perceptions and personal conviction and preference for a specific way of doing things was considered a challenge to knowledge transfer and putting into practice agreed methods or guidelines/ regulations:

> …[some] crew will say, 'I feel safer free climbing than clipping on.' That's a difficult one, but they feel it constricts them and they're safer without it [PPE]. It's complete nonsense obviously… this is going back some time [and] we've managed to eradicate. [R3]

Drawing on Simpson's (1996) cautious, confident and neutral cognitive frameworks regarding safety, we can identify that the organisational position and manager's perspectives lie within the cautious framework, yet the worker's statement offers indicators that align with the confident framework. Misalignment in the perceptions is likely to disrupt rather than enhance occupational health and safety practice.

Interpersonal relationships

All three respondents firmly believed that good interpersonal relationships were paramount to occupational health and safety practice:

> R1 *...if you don't know them, then you've got to learn…*
>
> R2 *The trust.*
>
> R1 *...when you work with someone for a long time, you know how it's going and you just [know what they're doing] ...*
>
> So we try and keep teams together, and that makes ginormous difference; if the team knows how they all work with each other, they know the manner of how people lift things up… [R3]

In both, the conversation recorded between the two workers (R1 and R2) and the interview with R3, trust emerges as a key theme central to interpersonal relationships.

Cautious mindset and co-creating safety

All three respondents also agreed that construction work is dangerous:

> …It's a high-risk industry and it always has been, whether when we first started or now, it's still a high-risk industry, because you're relying so much on other people all the time and machinery… [R1]
>
> We do have *accidents;* we do an awful lot of work… and I think it would be stupid to suggest that any company doesn't have accidents. [R3]

Awareness of the risk and potential for accidents are indicators that suggest a cautious mindset is relevant to these respondents. It sets appropriate awareness of circumstances and evolving situations, keeps people alert and thinking, observing and responding.

In terms of health, the workers also acknowledge wear and tear to body, and increase in health concerns over time as they age:

> It's very hard the building game. It's very hard on the body. The physical demands, you're lifting, your knees, your back… and when you get to our age things start to wear out… [R1]

Age also points to developments driven by generational shift in attitudes and values:

> …we find that the younger [ones] take to it [higher standards on OHS] because it is their future, and they understand the change… it's harder for some of the more- and we parted company with a couple of team leaders who couldn't really embrace the new way we were trying to do things, and it felt it was not something that they felt had value… That had a detrimental effect on the team. [R3]

The cautious mindset is evident in not only in health and safety awareness; it is discussed in relation to different roles of people on site, their connections with one another, and co-creating safety on site:

> R1 *...you get the safety guy who comes round and he goes, 'Oh, I don't like that' and you go, 'Well, what's wrong with it? How can he fall?' and you show them, 'How can he do this?' and they go, 'No, no, no. That shouldn't be like that.' You know, you're not going to work and put yourself in a position where you're going to fall. You're not going to do it. No one is going to do that. You're going to try and work as safely as you can and, hopefully, no one has an accident…*

> R2 *They're thinking of the paperwork…*

This conversation also highlights the different foci: practice vs paperwork, different priorities, and brings to fore the divide between experience and situated knowledge on the one hand vs theoretical/ ideological stance on the other hand.

Finally, in terms of co-creating safety on site, the workers mention that it is not only those with formal duty to watch out for occupational health and safety on site who spot and act on risk and potential danger. Workers are always looking out for one another, directly and indirectly:

> R1 *[if you saw something] you'd go and tell them... you would, always…*
>
> R2 *They might turn around and just say, 'sod off.'*
>
> R1 *Yes, if they tell you… say 'Well, okay, fair enough' and walk away… sometimes if you tell people they don't like it…*
>
> R2 *…people get aggressive.*

Leadership and organisational hierarchy

While collaboration and co-creating occupational health and safety were discussed, institutional mechanisms such as organisational hierarchy and leadership/ management structures were identified as influential themes in practice:

> Well, the management don't speak to us they'll only speak to Phil [the foreman]. That's on every job…" [R1]

Leadership on site level was specifically important to practice within the hierarchical organisation of work:

> We obviously do Toolbox talks, at the beginning of the day is what people are trying to do, but the most effective team leaders are the ones that give a quick briefing before every activity that they're about to undertake… it does help refocus people and get out any misunderstandings. [R3]

This aligns with the managerialist, top down rhetoric. Furthermore, similar rhetoric was evident in discussion about leadership with regards to other institutional mechanisms that impact on site practice, such as the role of the Health and Safety Executive (HSE) as a monitoring and enforcing body:

> …when the HSE, because they're much more active on coming on site now, and they've often been on site… [R3]

Rules

Alongside the abovementioned leadership and organisational hierarchy, rules emerged as a necessary aspect of occupational health and safety:

> …an ad hoc basis of safety is wrong. I think there has to be rules there and people need to stick to the rules. I do sense that if you just left it up to people to choose what they did when, some people would make inappropriate choices, and that would be a distraction. Therefore there needs to be rules, we set rules and we expect them to be met, and if they're not met we deal with it. [R3]

PPE was one theme that came up frequently in connection to rules, and the discussion attracted mixed views. R3 noted *"…It [PPE] is a brilliant idea and I could never understand why people would resist it…"* and he listed many items commonly used on building site as relevant to the work his company undertakes, including gloves, steel toecap boots, high visibility wear, hard hats, seatbelts, and climbing helmets. R3 also noted *"…I think PPE should be appropriate to what's done…"* and reflected on the principles of enforcement:

> *I think there has to be reason, if people make intelligent decisions that should be support, rather than just being dogmatic about something. I think that loses the credibility of HSE and PPE. [R3]*

Barriers: resistance, timescales, pricing and budgeting

The final theme we present draws attention to three barriers to good occupational health and safety practice: (i) resistance, (ii) timescales, and (iii) pricing and budgeting.

Resistance was mentioned above in relations to PPE, and it was also brought up in discussions about workers from different small firms working independently yet loosely together on larger sites:

> …a resistance when we were trying to do stuff was when it is observed that other companies on that site weren't being asked to work to the same principles, certain site workers were working to a different set of criteria, and our guys - you know - because wearing a hi vis when it's really hot, and not taking your shirt off… [R3]

Build timescales were also said to constrain good practice:

> …timescales we're given to construct things, which I've discussed with our competitors or colleagues in the sector, they feel that we're our own enemies to say we can do it in that time. If the elements turn against you, it's a constraint to try and push on that extra hour or deal with situations when it's wet and maybe getting dark… people are tired… [R3]

Most frequently mentioned barrier to good practice OHS on site was money: pricing and budgeting constraints.

> …they won't spend money on safety, They tell you to put gloves on and that doesn't cost a penny [to them], but when it comes to pricing [a job], put a scaffold for a walkway, they won't do it. [R2]

R3 reflected on staffing in relation to size of sites, and the presence of specialist personnel appointed to *"check on competence and ensure that our method statements are enacted… [but] it's very difficult within the pricing that our clients allow us…"* In his view such arrangements help *"drag up standards somewhat"* and therefore present an opportunity to develop good practice.

DISCUSSION AND CONCLUSION

The central research question in this paper was: *How do workers perceive and practice occupational health and safety on construction sites operated by micro firms?* We have employed social practice theory as the theoretical lens and presented an illustrative analysis of empirical data to answer this question. Our approach offers a new, integrative insight into occupational health and safety. Instead of focusing on normative 'best practice' we incorporate contextual and social categories of practice into the discussion. Table 1 below links social practice theory terms and the emergent themes relevant to our data.

Our data shows how individuals' attitudes, behaviours and choices are connected with occupational health and safety practice, and also, more importantly, we identify how occupational health and safety practices form, how they are reproduced, maintained, stabilised, challenged through the key themes that emerge from our empirical data.

Table 1: Practising occupational health and safety using social practice theory

Elements of social practice theory (after Reckwitz, 2002)	*Occupational Health and Safety practice*
Forms of bodily activities	Physically demanding and dangerous nature of work; environmental constraints
Forms of mental activities	Cautious mindset, different perceptions, resistance
'Things' and their use	Machinery, materials, PPE
A background knowledge in the form of understanding	Learning, training, experience, rules
Know-how	Competence, leadership, compliance
States of emotion	Resistance, change, looking to future
Motivational knowledge	Teamwork, interpersonal relationships, co-creating

Clearly our approach has limitations, particularly in terms of generalisability of the research findings, and hence we suggest that large scale studies are now designed to investigate and test the approach and ideas in different contexts. Further research is also needed to develop and deepen our understanding of social practice theory and how it may inform developments within occupational health and safety. For example, there are questions around the scope and nature of this concept, whether applied as a local construct that may be culturally bound, or alternatively universalist by nature.

REFERENCES

Andersen, L P, Karlsen, I L, Kines, P, Joensson, T and Nielsen, K J (2015) Social identity in the construction industry: Implications for safety perception and behaviour, *Construction Management and Economics*, 33(**8**), 640-52.

Blumer, H (1969) *Symbolic Interactionism: Perspective and Method*. Englewood Cliffs, NJ: Prentice-Hall.

Boardman, J and Lyon, A (2006) *Defining Best Practice in Corporate Occupational Health and Safety Governance*. Sudbury: Health and Safety Executive.

Bryman, A and Bell, E (2007) *Business Research Method, 2nd Edition*. Oxford: Oxford University Press.

Esmaeili, B and Hallowell, M.R (2012) Diffusion of safety innovations in the construction industry, *Journal of Construction Engineering and Management*, 138(**8**), 955-63.

European Agency for Safety and Health at Work (2019) *Leadership and Worker Participation*. https://osha.europa.eu/en/themes/leadership-and-worker-participation [Accessed 29 March 2019].

Hargreaves, T (2011) Practice-ing behaviour change: Applying social practice theory to pro-environmental behaviour change, *Journal of Consume*r Culture, 11(**1**), 79-99.

HSE (Health and Safety Executive) (2019) *Are You a Small Builder? Construction (Design and Management) Regulations 2015 (CDM 2015) - What You Need to Know*. http://www.hse.gov.uk/construction/areyou/builder.htm [Accessed 29 March 2019].

Hung, Y-H, Smith-Jackson, T and Winchester, W (2011) Use of attitude congruence to identify safety interventions for small residential builders, *Construction Management and Economics*, 29(**2**), 113-30.

Langford, D, Rowlinson, S M and Sawacha, E (2000) Safety behaviour and safety management: Its influence on the attitudes of workers in the UK construction industry, *Engineering, Construction and Architectural Management*, 7(**2**), 133-40.

Laukkanen, T (1999) Construction work and education: Occupational health and safety reviewed, *Construction Management and Economics*, 17, 53-62.

Orlikowski, W (2002) Knowledge in practice: Enacting a collective capability in distributed organising, *Organisation Science*, 13(**3**), 249-273.

Pink, S, Tutt, D, Dainty, A and Gibb, A (2010) Ethnographic methodologies for construction research: knowing, practice and interventions, *Building Research and Information*, 38(**6**), 647-659.

Reckwitz, A (2002) Toward a theory of social practices: A development in culturalist theorizing, *European Journal of Social Theory*, 5(**2**) 243-263.

Saunders, M, Lewis, P and Thornhill, A (2009) *Research Methods for Business Students 5th Edition*. Harlow, UK: Pearson Education.

Sherratt, F, Farrell, P and Noble, R (2013) UK construction site safety discourses of enforcement and engagement, *Construction Management and Economics*, 31(**6**), 623-635.

Shove, E and Pantzar, M (2005) Consumers, producers and practices: Understanding the invention and reinvention of Nordic walking, *Journal of Consumer Culture*, 5, 43-64.

Simpson, R (1996) Neither clear nor present: The social construction of safety and danger, *Sociological Forum*, 11(**3**), 549-562.

CORE VALUES THAT SUPPORT CONSTRUCTION HEALTH, SAFETY AND WELL-BEING (HSW)

John Smallwood[1]

Department of Construction Management, Nelson Mandela University, PO Box 77000, Port Elizabeth, 6031, South Africa

Values are an integral part of interventions relating to health, safety, and well-being. Literature indicates that seven core values and twenty-two value factors have been identified as supportive of HSW, the core values being: interconnectedness; participation; trust; justice; responsibility; development, and growth. A self-administered questionnaire survey was conducted among registered construction H&S practitioners in South Africa to determine the importance of, and perceived experience by workers of seven core values and twenty-two value factors in supporting HSW in construction. The findings include that 11 / 22 value factors are of near major to major / major importance in terms of supporting HSW in construction. However, perceived experience expressed as a percentage of importance, ranges between 48.6% and 66.7%. Conclusions include: the manifestation of core values and value factors is not conducive to HSW; well-being needs to be included in the H&S 'equation' and focused on; a holistic approach needs to be adopted relative to H&S, and workers' wider needs as reflected in the core values should be addressed. Recommendations include: H&S programmes need to be expanded to include well-being issues, and appropriate general management and human resource practices should be implemented in the business of construction, and on projects.

Keywords: core values, health and safety, value factors, well-being

INTRODUCTION

The report 'Construction Health and Safety Status and Recommendations' highlighted the considerable number of accidents, fatalities, and other injuries that occur in the South African construction industry (Construction Industry Development Board (CIDB), 2009). The report cited the high-level of non-compliance with H&S legislative requirements, which is indicative of a deficiency of effective management and supervision of H&S on construction sites as well as planning from the inception / conception of projects within the context of project management. The CIDB's report indicates the disabling injury incidence rate (DIIR) to be 0.98 i.e. 0.98 disabling injuries per 100 workers, the all industry average being 0.78, and a fatality rate of 25.5 per 100 000 workers, which does not compare favourably with international rates (CIDB, 2009).

Zwetsloot, van Scheppingen, Bos, Dijkman, and Starren (2013) argue that individual values are recognised as HSW influencing factors, however, they contend a good overview of HSW-related values is missing. Their study aimed to fill this gap by

[1] john.smallwood@mandela.ac.za

Smallwood, J (2019) Core Values That Support Construction Health, Safety and Well-Being (HSW) *In:* Gorse, C and Neilson, C J (Eds) *Proceedings of the 35th Annual ARCOM Conference,* 2-4 September 2019, Leeds, UK, Association of Researchers in Construction Management, 527-536.

identifying relevant values and clustering them into a limited set of core values supportive of HSW, the central research question being: What organisational values are supportive of HSW at work? Their central research question was operationalised into the following sub-research questions:

What organisational values or value-laden concepts are mentioned in the literature as relevant for HSW?

Can these values and value-laden concepts be logically clustered around a limited set of core values relevant for HSW?

Their study resulted in the development of a framework, which includes seven core values, twenty-two value factors, and three value clusters, that are supportive of HSW.

Given the abovementioned, an exploratory study was conducted in South Africa, the objectives being to determine the perceived importance of the seven core values, and twenty-two value factors in terms of supporting HSW as per the framework evolved by Zwetsloot, van Scheppingen, Bos, Dijkman, and Starren (2013), and the perceived experience of the seven core values, and twenty-two value factors by workers.

REVIEW OF THE LITERATURE

Values in General

Values are defined as: code of behaviour, ethics, standards (moral) and principles (Allen, 1990). The European Foundation for Quality Management (EFQM) (2013) in turn defines values as "operating philosophies or principles that guide an organization's internal conduct as well as its relationship with the external world. Values provide guidance for people on what is good or desirable and what is not. They exert major influence on the behaviour of individuals and teams and serve as broad guidelines in all situations."

The Identification of Core Values and Value Factors Relative to Health, Safety, and Well-Being

Twenty-nine values or value-laden concepts were identified by Zwetsloot, van Scheppingen, Bos, Dijkman, and Starren (2013), courtesy of the survey of the literature. This resulted in the need to evolve clusters of closely related value factors. Content analysis was then conducted, which entailed the following:

- A value factor was only attributed to the cluster it was judged most relevant for;
- What values were more central than other values or value-laden factors?
- Some value factors are 'essential values' - potentially relevant for the identity of organisations, and selected as core values, and
- Other factors appeared to be 'expressions of' such deeper values. For example, interconnectedness (core value), and 'social support' (an expression thereof).

The first workshop included fourteen stakeholders, who:

- Were required to clarify the meaning of core values;
- Provide feedback and associations with respect to the cultural factors identified, and
- Cluster the cultural factors and select a 'core value' for each cluster. The stakeholders evolved seven clusters versus the researchers' six clusters.

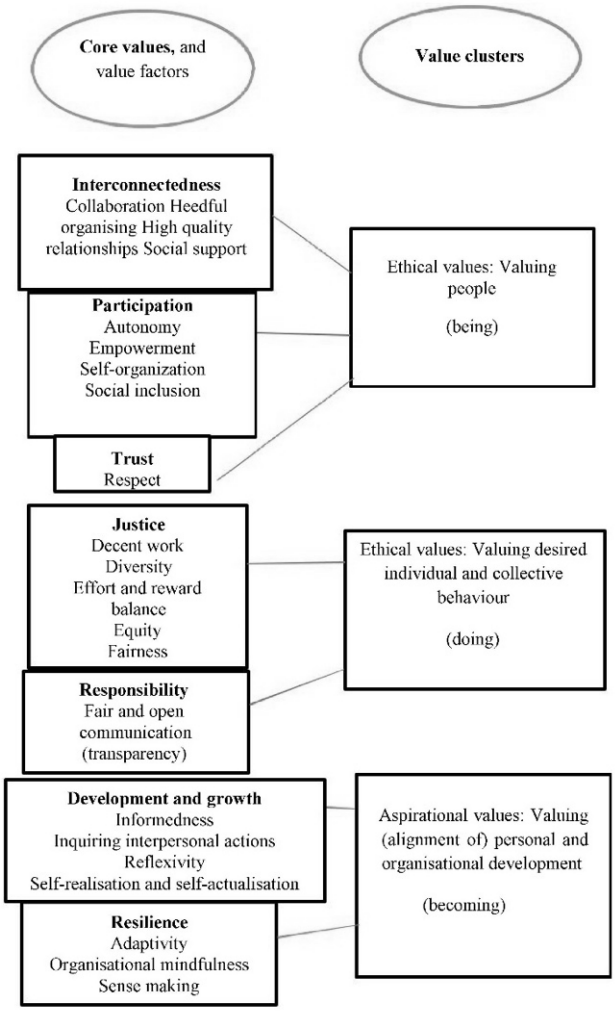
The second workshop included eight stakeholders, who:

- Were required to clarify the meaning of core values;
- Provide feedback and associations with respect to the cultural factors identified;
- Cluster the cultural factors and select a 'core value' for each cluster. The stakeholders evolved seven clusters versus the researchers' six clusters, and
- Finally, as a last step categorised the seven core values identified, which resulted in three main categories of core values that are supportive of HSW.

The process resulted in the development of a framework, which includes seven core values, twenty-two value factors, and three value clusters, that are supportive of HSW as presented in Figure 1. The three value clusters are:

- Ethical values: valuing people (being)';
- Ethical values: valuing desired individual and collective behaviour (doing), and
- Aspirational values: Valuing (alignment of) personal and organisational development (becoming).

Figure 1: A framework of core values, value factors, and value clusters that support HSW (Zwetsloot, van Scheppingen, Bos, Dijkman, and Starren, 2013)



RESEARCH

Research Method and Sample Stratum

The research method adopted the framework of core values, value factors, and value clusters that support HSW as evolved by Zwetsloot, van Scheppingen, Bos, Dijkman, and Starren (2013). The core values and value factors constituted the basis of the questionnaire in the form of two five-point Likert scale type questions, followed by a qualitative question, and six close ended demographic questions.

The questionnaire was sent per e-mail to all South African Council for the Project and Construction Management Professions (SACPCMP) registered Professional Construction Health and Safety Agents (CHSAs), Candidate Construction H&S Agents (Can CHSAs), and Construction H&S Managers (CHSMs) throughout South Africa, per e-mail. Table 1 presents the sample strata details and response rates.

Table 1: Sample strata details and response rates

Sample stratum	Size (No.)	Response (No.)	Response rate (%)
CHSAs	78	14	18.0
Can CHSAs	124	14	11.3
CHSMs	562	26	4.6
Mean	764	54	7.1

Due to the low mean response rate, the findings can be deemed to be indicative, however, they are likely to be from the more committed practitioners, and practitioners that are familiar and / or interested in the subject area, which reinforces the validity of the findings.

Research findings

Table 2 indicates the importance of seven core values and twenty-two value factors in terms of supporting HSW in construction in terms of percentage responses to a scale of 1 (not) to 5 (very), and mean scores (MSs) between 1.00 and 5.00. It is notable that all the MSs are above the midpoint value of 3.00, which indicates that the respondents perceive the value factors to be more than important as opposed to less than important in terms of supporting HSW in construction.

In terms of the collective importance of core values, responsibility (4.76) is ranked first followed by respect (4.70), resilience (4.30), justice (4.27), interconnectedness (4.08), participation (3.96), and development and growth (3.92). The collective MSs and rankings have been emboldened in the MS and rank (R) columns.

A review of the MS ranges provides further insight with respect to the importance of the value factors. It is notable that 11 / 22 (50.0%) MSs > 4.20 ≤ 5.00, which indicates that the value factors are between more than important to very / very important. The top ten value factors are ‘fair and open communication (transparency)’ (core value: responsibility), followed by eight ‘respect’ value factors, namely ‘respect’, ‘fairness’, ‘decent work’, effort and reward balance’, ‘organisational mindfulness’, ‘collaboration’, ‘informedness’, ‘quality relationships’, and ‘justice’, and then ‘adaptivity’ (core value = resilience).

The remaining 11 / 22 (50.0%) MSs > 3.40 ≤ 4.20, which indicates that the value factors are between important to more than important / more than important.

Table 2: The importance of core values / value factors

Core value / Value factor	U	Response (%) Not ..... Very 1	2	3	4	5	MS	R
Interconnectedness:							4.08	5
• Collaboration	0.0	0.0	5.6	7.4	33.3	53.7	4.35	8
• Heedful organising	0.0	0.0	5.6	14.8	42.6	37.0	4.11	14
• Quality relationships	0.0	1.9	1.9	9.3	38.9	48.1	4.30	9
• Social support	1.9	3.7	7.4	22.2	27.8	37.0	3.81	18
Participation:							3.96	6
• Autonomy	0.0	5.6	5.6	27.8	37.0	24.1	3.69	21
• Empowerment	0.0	1.9	1.9	22.2	24.1	50.0	4.19	13
• Self-organisation	0.0	1.9	1.9	18.5	31.5	46.3	4.19	12
• Social inclusion	0.0	3.7	7.4	31.5	22.2	35.2	3.78	19
Respect:							4.70	2
• Respect	0.0	0.0	3.7	1.9	14.8	79.6	4.70	2
Justice:							4.27	4
• Decent work	1.9	0.0	3.7	3.7	29.6	61.1	4.43	4
• Diversity	0.0	1.9	5.6	11.1	44.4	37.0	4.09	15
• Effort and reward balance	0.0	1.9	3.7	1.9	35.2	57.4	4.43	5
• Equity	0.0	3.7	7.4	24.1	20.4	44.4	3.94	16
• Fairness	0.0	0.0	0.0	13.0	25.9	61.1	4.48	3
Responsibility:							4.76	1
• Fair and open communication (transparency)	0.0	0.0	1.9	3.7	11.1	83.3	4.76	1
Development and growth:							3.92	7
• Informedness	1.9	0.0	1.9	7.4	35.2	53.7	4.35	7
• Inquiring interpersonal actions	5.7	1.9	3.8	17.0	45.3	26.4	3.74	20
• Reflexivity	5.6	1.9	5.6	24.1	31.5	31.5	3.69	22
• Self-realisation and self-actualisation	1.9	0.0	7.5	24.5	30.2	35.8	3.89	17
Resilience:							4.30	3
• Adaptivity	0.0	0.0	1.9	17.0	34.0	47.2	4.26	10
• Organisational mindfulness	0.0	0.0	0.0	11.3	39.6	49.1	4.38	6
• Sense making	0.0	0.0	3.8	17.0	28.3	50.9	4.26	11

Table 3 indicates the experience of seven core values and twenty-two value factors in terms of supporting HSW in construction by workers in terms of percentage responses to a scale of 1 (minor) to 5 (major), and MSs between 1.00 and 5.00. It is notable that no MSs are above the midpoint value of 3.00, which indicates that the respondents perceive the value factors to be experienced by workers infrequently as opposed to infrequently by workers.

In terms of the collective experience of core values, justice (2.97) is ranked first, followed by justice (2.97), respect (2.96), responsibility (2.87), interconnectedness (2.83), resilience (2.81), development and growth (2.72), and participation (2.56). The collective rankings have been emboldened in the rank (R) column.

A review of the MS ranges provides further insight with respect to the experience of the value factors. It is notable that no MSs > 4.20 ≤ 5.00 - between a near major to major / major extent. Similarly, in the case of > 3.40 ≤ 4.20 - between some extent to a near major / near major extent. Then, 19 / 23 (82.6%) MSs > 2.60 < 3.40 - between a near minor extent and some extent / some extent. The top ten value factors are: three 'justice' value factors, namely 'decent work', 'diversity', and 'effort and reward balance', followed by an 'interconnectedness' value factor 'collaboration', then 'respect' (core and value factor), then two 'justice' core values 'equity', and 'fairness', then two 'interconnectedness' value factors 'quality relationships', and 'heedful organising', and ' resilience' value factor' organisational mindfulness'.

Table 3: The experience of core values / value factors by workers

Core value / Value factor	U	Response (%) Minor ..... Major 1	2	3	4	5	MS	R
Interconnectedness:							2.83	4
• Collaboration	0.0	5.8	30.8	36.5	13.5	13.5	2.98	3
• Heedful organising	1.9	5.8	34.6	34.6	11.5	11.5	2.88	10
• Quality relationships	1.9	1.9	36.5	38.5	11.5	9.6	2.90	7
• Social support	0.0	13.7	33.3	33.3	11.8	7.8	2.67	17
Participation:							2.56	7
• Autonomy	3.9	17.6	39.2	21.6	9.8	7.8	2.49	22
• Empowerment	1.9	9.6	42.3	30.8	3.8	11.5	2.65	18
• Self-organisation	0.0	11.8	49.0	17.6	15.7	5.9	2.55	20
• Social inclusion	0.0	21.6	33.3	23.5	11.8	9.8	2.55	21
Respect:							2.96	2
• Respect	1.9	13.5	25.0	25.0	21.2	13.5	2.96	6
Justice:							2.97	1
• Decent work	0.0	9.6	19.2	40.4	19.2	11.5	3.04	1
• Diversity	0.0	11.5	25.0	28.8	21.2	13.5	3.00	2
• Effort and reward balance	0.0	15.4	23.1	28.8	23.1	9.6	2.88	9
• Equity	0.0	11.5	25.0	30.8	21.2	11.5	2.96	4
• Fairness	0.0	13.5	25.0	30.8	13.5	17.3	2.96	5
Responsibility:							2.87	3
• Fair and open communication (transparency)	0.0	17.3	28.8	21.2	15.4	17.3	2.87	11
Development and growth:							2.72	6
• Informedness	3.8	9.6	32.7	26.9	15.4	11.5	2.86	12
• Inquiring interpersonal actions	5.8	9.6	36.5	26.9	13.5	7.7	2.71	15
• Reflexivity	9.6	7.7	44.2	19.2	11.5	7.7	2.64	19
• Self-realisation and self-actualisation	5.8	13.5	36.5	21.2	13.5	9.6	2.67	16
Resilience:							2.81	5
• Adaptivity	0.0	7.7	30.8	40.4	15.4	5.8	2.81	13
• Organisational mindfulness	0.0	11.5	28.8	30.8	17.3	11.5	2.88	8
• Sense making	0.0	13.5	34.6	28.8	11.5	11.5	2.73	14

Table 4 presents a comparison of the importance and experience of core values / value factors by workers in terms of MSs between 1.00 and 5.00, and the percentage experience constitutes of importance.

In terms of the percentage experience constitutes of the importance of value factors, the percentages range between 48.6% (self-organisation) and 66.7% (equity). The ten highest percentages are relative to equity (66.7%), diversity (64.7%), inquiring interpersonal actions (62.4%), reflexivity (61.0%), heedful organising (60.5%), decent work (59.5%), social support (59.4%), collaboration (59.1%), self-realisation and self-actualisation (57.8%), and quality relationships (57.6%).

In terms of the percentage experience constitutes of the importance of core values, the percentages range between 49.7% (responsibility) and 60.1% (justice).

Respondents were requested to provide comments in general regarding the recognised value factors in terms of their role in the HSW of construction workers.

Table 4: Comparison of the importance and experience of core values / value factors by workers

Core Value / Value Factor	Imp	MS Exp	Exp. % of Imp.
Interconnectedness:	4.08	2.83	59.3
• Collaboration	4.35	2.98	59.1
• Heedful organising	4.11	2.88	60.5
• Quality relationships	4.30	2.90	57.6
• Social support	3.81	2.67	59.4
Participation:	3.96	2.56	52.7
• Autonomy	3.69	2.49	55.4
• Empowerment	4.19	2.65	51.7
• Self-organisation	4.19	2.55	48.6
• Social inclusion	3.78	2.55	55.8
Trust:	4.70	2.96	53.0
• Respect	4.70	2.96	53.0
Justice:	4.27	2.97	60.1
• Decent work	4.43	3.04	59.5
• Diversity	4.09	3.00	64.7
• Effort and reward balance	4.43	2.88	54.8
• Equity	3.94	2.96	66.7
• Fairness	4.48	2.96	56.3
Responsibility:	4.76	2.87	49.7
• Fair and open communication (transparency)	4.76	2.87	49.7
Development and growth:	3.92	2.72	59.0
• Informedness	4.35	2.86	55.5
• Inquiring interpersonal actions	3.74	2.71	62.4
• Reflexivity	3.69	2.64	61.0
• Self-realisation and self-actualisation	3.89	2.67	57.8
Resilience:	4.30	2.81	54.7
• Adaptivity	4.26	2.81	55.5
• Organisational mindfulness	4.38	2.88	55.6
• Sense making	4.26	2.73	53.1

Selected comments include:

> Workers are seen as a resource to complete a project, and when the project is running down they are de-mobbed as soon as possible, irrespective of the value they can add to the company they have been working for."

> Workers are bullied into a situation where it is clear that they must do as senior staff insist or face penalties, sometimes even loss of employment, this has the effect that workers do as they are told. I, for one had many discussions with the workers at grassroots level and I know that they DO have positive contributions to make, yet that are not given the chance."

> Further research is required re decent work environments. The South African government and private procurement systems should modernise their systems to allow for greater transparency throughout their supply chains. The UK's recent launch of their Modern Slavery Act could be used as a starting point."

DISCUSSION

As stated earlier in the paper, due to the low response rate, the findings can be deemed to be indicative, however, they are likely to be from the more committed practitioners,

and practitioners that are familiar and / or interested in the subject area, which reinforces the validity of the findings.

Although it can be argued that workers were not surveyed to determine the importance of, and their experience of core values / value factors, the general level of education of South African workers is such that workers would likely not have understood and appreciated the respective core values / value factors.

Extensive research has been conducted relative to values, however, as stated by Zwetsloot, van Scheppingen, Bos, Dijkman, and Starren (2013), although individual values are recognised as HSW influencing factors, a good overview of HSW-related values is missing. Therefore, the study focused on the importance of HSW-related values in the form of core values / value factors, and the perceived experience thereof by workers.

Given the percentage 'perceived' experience constitutes of the importance of value factors, clearly there is major potential for improvement. Furthermore, given that this is 'perceived', the 'actual experience' according to workers may be lower.

The mean MS in terms of the importance of the value cluster 'valuing people' (being) comprised of the core values interconnectedness, participation, and trust is 4.25, and in terms of experience is 2.78. The mean MS in terms of the importance of the value cluster 'valuing desired individual and collective behaviour (doing)' comprised of the core values justice and responsibility is 4.52, and in terms of experience is 2.92. The mean MS in terms of the importance of the value cluster 'aspirational values: valuing (alignment of) personal and organisational development (becoming)' comprised of development and growth, and resilience is 4.11, and in terms of experience is 2.77. It is notable that the value cluster 'valuing desired individual and collective behaviour (doing)' is ranked first in terms of importance. However, the MS is skewed by the MS of the 'responsibility' core value (4.76). Although, the partner MS of the 'justice' core value is substantially lower, namely 4.27, three value factors' MSs are notable, namely fairness (4.48), decent work (4.43), and effort and reward balance (4.43).

Given the importance of the seven core values, and twenty-two value factors in terms of supporting HSW according to the literature, and the empirical findings, a holistic approach characterised by a focus on the respective core values and value factors is required. The traditional focus on H&S issues is clearly insufficient, and appropriate general management and human resource practices should be implemented in the business of construction, and on projects.

Furthermore, currently the focus of H&S programmes in the South African construction industry is on H&S, and in turn, more on safety than on health issues, let alone wellbeing issues (Smallwood, 2015). However, the irony is that many of the core values and value factors that constitute wellbeing issues impact directly on H&S performance, namely: collaboration, and heedful organising (interconnectedness); autonomy, empowerment, and self-organisation (participation); effort and reward balance (justice); fair and open communication - transparency (responsibility); informedness, and inquiring interpersonal actions (development and growth), and adaptivity, organisational mindfulness, and sense making (resilience). Then, manifestation of many of the core values and value factors are dependent on optimum H&S: respect (trust); decent work, equity, and fairness (justice), and self-realisation and self-actualisation (resilience).

CONCLUSIONS

Given the importance of the core values and value factors in terms of supporting HSW, it can be concluded that a holistic approach needs to be adopted relative to H&S, and that well-being needs to be included in the 'equation' and focused on. Furthermore, it is no longer a case of merely employing workers and addressing H&S, but rather addressing workers' wider needs as reflected in the core values: responsibility; respect; resilience; justice; interconnectedness; participation and development and growth.

Given that the perceived experience of the value factors by workers expressed as a percentage of importance ranges between 48.6% and 66.7%, it can be concluded that the nature of the construction industry in the form of the manifestation of value factors is not conducive to HSW. This conclusion has implications for the construction industry in the short to medium term as workers may no longer be willing to entertain the status quo. Furthermore, the construction industry may be viewed as a 'last resort', and therefore may not attract the preferred 'employee'.

The empirical findings reinforce the relevance of the framework as evolved by Zwetsloot, van Scheppingen, Bos, Dijkman, and Starren (2013) in terms of the importance of the core values, and value factors, which framework was not empirically tested.

RECOMMENDATIONS

Appropriate general management and human resource practices should be implemented in the business of construction, and on projects, and should precede or at least accompany HSW practices and interventions. A case of simply applying the basics of construction management, and more specifically industrial psychology principles, which manifests itself in the form of the seven core values, and twenty-two value factors.

The construction industry first needs to focus on the health component of H&S, and realise that well-being is an essential component of the 'duty of care' and respect for people.

H&S programmes need to be expanded to increase focus on the health component, and to include well-being issues, which are represented by the seven core values, and twenty-two value factors. Therefore, employer associations should provide leadership, raise, or for that matter, create awareness relative to well-being, and amend their industry-wide H&S programme, H&S star grading, and H&S competition programmes.

All professional associations, especially H&S and construction management associations, and statutory built environment councils should provide leadership, raise, or for that matter, create awareness relative to well-being, and evolve practice notes relative to HSW.

Tertiary built environment education, especially construction management, needs to address well-being issues.

All stakeholders need to be conscious and mindful of the implications of project-wide decisions on the HSW of the construction team, and especially workers, who are generally from the low-income group, and vulnerable.

REFERENCES

Allen, RE (1990) *The Concise Oxford Dictionary of Current English 8 Edition*. New York: Oxford University Press, Inc.

Construction Industry Development Board (CIDB) (2009) Construction Health and Safety in South Africa Status and Recommendations. Pretoria: CIDB.

European Foundation for Quality Management (EFQM) (2013) *European Foundation for Quality Management Excellence Model*. Brussels: EFQM.

Smallwood, JJ (2015) Optimising the Elements of a Construction Health and Safety (H&S) Programme and Audit System, *In*: *Proceedings 9th Brazilian Symposium on Construction Management and Economics (SIBRAGEC)*, 7-9 October 2015, São Carlos, Brazil, 399-406.

Zwetsloot, G I J M, van Scheppingen, A R, Bos, E H, Dijkman, A and Starren, A (2013) The core values that support health, safety, and well-being at work, *Safety and Health at Work*, 4, 187-196.

INVESTIGATION INTO HOW TECHNOLOGY CAN OVERCOME LANGUAGE BARRIERS EXPERIENCED BY CONSTRUCTION WORKERS FROM EASTERN EUROPE ON SITES IN LONDON

Ilie Cocerhan and J Bradley[1]

School of Engineering, University of Limerick, Limerick, V94 T9PX, Ireland

Construction sites are dynamic, complex work environments where safety, quality of work and productivity are all key metrics for the success of a project. In a complex environment the ability to communicate and for the communication to be translated in to effective and efficient actions is critical, therefore on construction sites in London, the ability to speak and understand English is of paramount importance. With the number of foreign workers in the construction industry on the rise in the United Kingdom (UK) a significant proportion of the construction workforce have very little or no English. These non-English speaking workers face many issues daily, for example the ability to communicate effectively on site and also have problems in the longer term regarding integrating into the workplace. From a Health and Safety (H&S) perspective, of the 16 migrant/foreign workers that suffered fatal injuries in construction in 2016, four died on the first day and 50% died within the first 10 days on site. The research presented in this paper is a pilot study to investigate the impact of poor language skills on site and focuses on a subgroup of foreign workers, namely those from Romania, and looks at the use of a simple assistive technology to help reduce the problem. The researcher, fluent in both Romanian and English conducted interviews with site managers and Romanian workers on 3 London construction sites to establish the level of English-speaking ability and how foreign workers viewed the Site Induction Process (SIP). The responses showed that SIP is seen by the workers as something that has to be done, a tick-box exercise that adds no value since they cannot understand the content. Due to the poor English-speaking ability of workers, instructions are primarily conveyed through demonstrations so a significant amount of time is wasted on site as instructions, comments and signage must be translated constantly, with cultural gatekeepers regularly called upon to translate and interpret. This was shown when workers were instructed to complete simple tasks by an English-speaking manager with and without the use of assistive technology to translate, and workers performance gauged in terms of health and safety, the time taken, the involvement of other people and whether the task was completed. The results from this pilot study indicated the value of Google Translate as an assistive technology on site for workers with a low ability to speak English, potentially adding value to both the SIP and the ability to follow instructions and complete tasks.

Keywords: Assistive technology, foreign workers, H&S, induction, language barriers

[1] jim.bradley@ul.ie

Cocerhan, I and Bradley, J (2019) Investigation into How Technology Can Overcome Language Barriers Experienced by Construction Workers from Eastern Europe on Sites in London *In:* Gorse, C and Neilson, C J (Eds) *Proceedings of the 35th Annual ARCOM Conference,* 2-4 September 2019, Leeds, UK, Association of Researchers in Construction Management, 537-545.

INTRODUCTION

The number of migrant workers has more than doubled in the UK in the last 15 years, with construction having the highest percentage of migrant workers (Office for National Statistics, 2018) Many are unable to speak English. They work and socialise primarily with other foreign workers, so they do not have any incentive to learn the English language.

The lead researcher observed the impact of this during the SIP where Romanian workers who could not speak English were present for the SIP training delivered solely through English. The problem of language is further compounded by lack of experience, no understanding of the UK regulations governing Health and Safety (H&S) on site and cultural differences. New workers are higher risk (Trotto, 2016) but new workers with language difficulties magnify the risk. The key question has to be how would these workers cope on site? For instance, they have no knowledge of the fire safety procedures on site and if they've never worked on site before they will have no idea what to do should a fire break out - despite having gone through the SIP.

Language barriers can impact on H&S, quality and productivity aspects on site and cause frustration when cultural gatekeepers are frequently called upon in order to translate instructions and information. Not only are the cultural gatekeepers disturbed from the task they are carrying out, but the manager and workers are also losing valuable time.

The literature shows that sensing and warning-based technologies are already being used to improve H&S in construction (Antwi-Afari *et al.,* 2019). This led to the research question - could assistive technology be used during the Site Induction Process and also when giving instructions to make sure everybody understands the Site Induction Process and instructions fully? The use of Google Translate as a zero-cost assistive technology (workers all had smart phones but were unaware of the translation apps available) was investigated and the outcome showed a positive effect.

Literature Review

Research published as part of the Secretary of State for Work and Pensions Inquiry into the Underlying Causes of Accidents in Construction in 2017 revealed that Health and Safety Executive (HSE a, b and c, 2018) Inspectors repeatedly identify that foreign or migrant workers are potentially at greater risk than British born workers because of language skills, inexperience, lack of understanding of UK Health and Safety standards and cultural differences.

The HSE (b, 2018) has recommendations on dealing with language issues, such as providing English courses for workers who need to improve their English or have no English at all. Although Health and Safety law in the UK doesn't require workers to be able to speak English, learning English reduces communication difficulties and has been shown to lead to higher productivity and retention rates, as well as promoting integration outside work.

Employers have a duty to provide understandable information to workers - this does not have to be in writing, or necessarily in English. Therefore, it would seem to be in the employers' best interest to provide English classes.

Other recommendations from the HSE involve using translators, having a buddy system on site, using pictograms as opposed to text on signs and using clear and simple English in training sessions or when giving instructions.

Communication on-Site Between Migrant Workers and Managers

In a study published by CITB (CITB, 2011), focused on Migrant Construction Workers and Health and Safety Communication showed that extensive research has been carried out in improving the health and safety on a construction site for migrant workers using simple actions such as sign translation. Recognising the role of translators and interpreters is important as most of the communication on site between a non-English speaking and an English-speaking worker or manager is through a cultural gatekeeper, "The terms 'translate' and 'interpret' are often used interchangeably in everyday, non-technical language, but formal translation (written) and interpretation (oral) work are highly skilled and regulated professions." (CITB, 2011). Rodrigues (1996) advised that the translators, interpreters or cultural gatekeepers' job is weighty and almost always without proper training as they are only using their on-site learned English to translate. Even with a professional translator is it is estimated that up to 40% of the intended meaning of the message is lost (Loosemore and Lee, 2002). For example, workers do not understand the terminology encountered on site including basic words such as ''hazardous'' and ''risk management'' (Loosemore and Andonakis, 2007).The dangers facing migrant workers who had low English proficiency were highlighted in the study by Trajkovski and Loosemore (Trajkovski and Loosemore, 2006).

Culture

According to Loosemore, and Andonakis (2007), there are many cultural variables that influence inter-cultural communication such as attitudes, social organisation, thought patterns, roles, non-verbal behaviour, and language - the consequence is that messages can often be misinterpreted. Construction sites in London are made up of several different cultures, mostly Eastern European. This leads to a level of isolation and also to a thought process

Technology

The technology presented in the literature currently appears to be focused on wearables designed for sensing or giving warnings from a H&S viewpoint or to enhance communication and productivity (Antwi-Afari *et al.,* 2019). Building Information Modelling (BIM) can be considered as assistive technology in that it allows access to 3D representations of what is to be built and also allows immersive virtual and augmented reality technologies to 'show' what the site locations should look like (Koseoglu and Nurtan-Gunes (2018). The presence of a 'digital skin' as a context aware network of sensors that could make the tracking and tracing of workers, materials and the overall progress of work on the construction site, available in real time, is well accepted as offering huge potential benefits in the management of H&S and productivity (Edirisinghe, 2019).

Throughout the literature reviewed, there was no mention found of how assistive technology could be used to eliminate some of the language barriers on site. As a very basic cost-free assistive technology, Google Translate has the potential to provide a solution to the problem of language difficulties on construction sites. It can translate a picture taken on a mobile phone automatically and with the recent advancements, it can now translate hand writing. Posters and health and safety notices could be translated with ease. A new Conversation feature was introduced recently which allows real-time conversation translation. The challenge is how to move away from the conventional gatekeeper/ foreman translation and introduce the assistive technology on sites.

Site Induction
Research published by CITB, concluded that SIP needs to be redefined (CITB, 2011). There has to be work done on how to make SIP more understandable for foreign workers as workers as there is a suggestion that they will nod their heads when asked if they've understood. In the advice for employers on the HSE website they suggest 'Consider the needs of workers who may not speak English well, if at all, and whether you need translation services' (HSE, 2018).

The HSE states that new workers are as likely to have an accident in the first 6 months of work as they are in the entire remainder of their working career (HSE a, 2018). Site Induction is critical because according to statistics from the HSE (HSE c, 2018) of the 16 foreign construction workers killed in incidents at work in the UK in 2015, four died on their first day on site and 50% of the fatalities occurred during the first 10 days on site. To reduce this figure, one possible approach could be should be to focus on CSCS cards provision and SIP as they are the two requirements to be able to work on any site in the UK.

CSCS cards
A CSCS card is necessary to be able to access any construction site in the UK. The test for a CSCS card can be done in English or by getting a voice over or have an interpreter in the following languages: Bulgarian, Czech, French, German, Hungarian, Lithuanian, Polish, Portuguese, Punjabi, Romanian, Russian and Spanish (Construction Helpline, 2018). These languages cover most foreign workers in the construction industry which allows workers using the languages as listed to walk onto construction sites with no English-speaking capabilities.

Even though there is no English level requirement when completing the exam to obtain a CSCS card, once the worker has a CSCS card most employers take it that he/she is aware of the basic health and safety risks on a site. "Many admitted to pretending to understand English in case it stopped them getting work, or of losing their jobs if their lack of English became known" Health and Safety Executive (2018). This nullifies the benefit of the CSCS card that should be acting as a screening method to ensure those on site had basic knowledge and so puts the holder and their work colleagues at risk.

RESEARCH DESIGN

This pilot study was built on undertaking qualitative research to explore the impact to of language barriers on three London construction sites, with 30 semi-structured interviews, to gain the subjective viewpoints of non-English speaking workers and their managers. The interviews were all conducted in an open-ended format, face-to-face and focused on Romanian and Albanian workers as the lead researcher is fluent in Romanian and as such could directly interact with the people interviewed. All pre-determined questions or relevant probes were tabled in the same style and order with responses noted accordingly, to improve replicability of results. The interview subjects were two Contracts Managers, three Project Managers, one Site Manager, one Health and Safety Manager and two Site Engineers, four Foremen and 17 site workers. The managers were targeted because they have to deal with language barriers daily. The workers selected were mainly Romanian or Albanian. The focus of the interview was to establish the level of English comprehension that the workers had, its impact on their productivity and safety and on how to use the newly available technology of Google Translate to deal with language barriers in critical areas such as SIP.

On-site, tests (as outlined below) were carried out to see if an assistive technology, in this case Google Translate, could be of benefit as a translation tool on site and its effect observed. As already stated, these tasks were used to show the effect of the translation app as a means of reducing the language barrier for relatively inexperienced workers. More complex tasks would involve training and support or more experienced workers and so fall outside the scope of this work. The tests used involved simple tasks that required little or no experience or training and had negligible risk from the H&S perspective and could be monitored in terms of time taken, number of people involved, the actual completion of the job and whether there were any unforeseen H&S implications. The focus was solely on the impact of the translation technology on the ability to do the simple task.

As controls, the two tests were done without any assistive technology and involved an English-speaking manager giving a task to a non-English speaking worker verbally or in writing. Tests that involved similar tasks were then given to the same workers but this time they utilised Google Translate Photo and Conversation. The data from the tests was gathered by observing the worker's performance and the quality of the completed task.

Test 1: Task instructions given with and without Google Translate Picture;

- As a control, an English-speaking manager gives a non-English speaker a task to carry out which is typed out on a page in English with no diagrams or pictures. The task was to collect all the steel rubbish around a small area on site and to ensure it was placed into the 'Metal Only' skip
- The researcher monitors the worker to see how he manages the task in terms of how long it takes him, are there any Health and Safety implications, and was there an intervention by any other worker and whether the task was completed.
- The same worker is then given a similar task by the same manager in the same way. The task was to go to another area of the site and collect all the waste timber that had to be placed in the 'Timber Only' skip. This time, the worker also receives a data sheet showing him how to use the Google Translate Picture feature on his smart-phone to translate the document.
- The researcher monitors the worker to see how he performs the task after using the Google Translate Picture technology to translate the instruction.

Test 2: Task instructions given with or without Google Translate Conversation;

- As a control, an English-speaking manager communicates a task that is required to be completed verbally to a different non-English speaking worker to the best of his ability. The manager verbally gave instructions about a task to the worker. He used short sentences and as simplistic a language as he possibly could. The task was to place a Fire Point Unit on the 1st level of the slip-form which included 2 fire extinguishers, an eye cleaning toolkit etc.
- The researcher monitors the worker to see how he manages the task in terms of how long it takes him, are there any Health and Safety implications, and was there an intervention by any other worker and whether the task was completed.
- The manager then communicates a similar task to the same worker but this time the Conversation feature on Google Translate is used, which allows instant real-time translations.
- The researcher monitors the worker to see how he performs the task using the Google Translate Conversation technology.

RESULTS

In this pilot study, a total of 30 people were interviewed and when asked about their English speaking ability, six spoke English as their first language and 19 of the remaining 24 stated that they had or would lie about their English-speaking abilities in case they wouldn't get or would lose a job. There were eight people who stated that their English is below poor and five of these stated that they would not be interested in taking English classes. All had a smartphone with access to the internet, yet only one out of these 30 people had previous knowledge of the Google Translate feature and that it was available for free. This is a missed opportunity for improving communication on site as it shows that the construction workers aren't being made aware of free assistive technologies that are available to them.

It was found that 85% of the people interviewed strongly agree and 10% somewhat agree that the SIP used on site was ineffective, rating it as either very poor or poor. Most people interviewed considered the SIP as something that must be done to get on site. It was not seen as being a source of vital health and safety information, such as fire escape routes and site-specific rules. The construction workforce on the sites surveyed, clearly had no belief in the effectiveness of the induction process in its current format. When asked what recommendations they had on how to change the current SIP, 18 responses indicated there should be a translator in every induction room with 15 responses stating that there should at least be a video of the SIP in every language.

At the end of the interview, the researcher showed the workers and managers the features available on Google Translate - both Picture and Conversation. 100% of the people interviewed, including the one person that knew about the features when asked, stated that they would find Google Translate very useful to translate during the Induction process, putting it ahead of the solutions they previously suggested as outlined above.

Of the 30 people interviewed, 14 believed it was too easy to obtain a CSCS card, especially as they can do it in their own language (apart from Albanian) and therefore have no need to speak English to obtain their CSCS card. When asked about how they currently communicate with other workers that do not speak the same language or don't have good English-speaking capabilities, 21 people said that they do it through demonstration i.e. they ask someone to show them how to perform the task. Skilled workers that have good English must show low skilled workers with poor English how to do tasks using minimal and simple English. However, people doing translations and interpreting on site are neither recognised or qualified. They are simply picked out from the workers on site because they have a higher level of English-speaking capability than the other foreign nationals on site. The use of the Google Translate technology may lead to these 'unofficial' translators being able to concentrate on their own job and experience less interruptions.

Test Results

The control aspect of the first test to show the effect of the assistive technology involved an English-speaking manager giving a Romanian non-English speaking worker written instructions on a task - to collect all the steel rubbish around a small area on site and to ensure it was placed into the 'Metal Only' skip. The worker could not understand the written instructions detailing what he was to do. The worker sought out on site the storeman who he knew had good English and got him to

translate. This added time to his completion of the task and involved taking up another worker's time.

The next part of the first test involved the same two people but a slightly different task. This time the task was to go to another area of the site and collect all the waste timber that had to be placed in the 'Timber Only' skip. Before the manager gave the worker the task the researcher showed the worker the Google Translate Picture feature on their smartphone. Once the worker received the written instructions detailing the task, he was able to translate it instantly on his smartphone and proceed immediately with the task. He did not require any help from anyone so there was no time wasted. The area was cleared in half the time that it took the same worker to clear a similar area of a similar material. Since the worker spent less time doing the task, his exposure to any risk was also reduced.

The control aspect of the second test involved a different Romanian worker, chosen because he had very poor English, and the same manager. The manager verbally gave instructions about a task to the worker. He used short sentences and as simplistic a language as he possibly could. The task was to place a Fire Point Unit on the 1st level of the slipform which included 2 fire extinguishers, an eye cleaning toolkit etc. The worker nodded like he knew what he had to do but in fact, he had no idea as he returned 10 minutes later with a foreman to ask again. The task remained incomplete.

The next part of the second test involved the same worker and manager as above. The task remained the same as the worker didn't have any knowledge of what he had to do. The researcher showed the worker how to use Google Translate Conversation before the manager proceeded to instruct him on the task. The manager used short sentences and spoke slowly so Google Translate could pick up everything he was saying. The worker was able to understand all the information about the task. No other site personnel got involved and the task was completed quickly and safely by the worker.

It should be pointed out that the tasks involved in the test were very simple and required little or no experience to complete so any problems with completion were down to the workers inability to speak English. Other more complex tasks would require more than the translation of the instructions, but as a pilot study, the usefulness of Google Translate was demonstrated.

CONCLUSIONS

It needs to be stated that this pilot study showed the potential benefit of using Google Translate as a simple assistive technology on site, helping with the translation of instructions or training such as SIP. The functionality of this assistive technology is also recognised as being dependent upon the availability of Wi-Fi, the quality of the Smartphone and of course the reliability and accuracy of the translation. It is also recognised that, on site performance and H&S compliance are dependent on more than just translation. The influence of management style, level of pressure on the site, experience and cultural viewpoint of both the workforce and their supervisors also have a huge part to play in the interpretation of what has been translated. However, with the advent of highly sophisticated, and expensive assistive technologies coming on site as tools to facilitate BIM, the introduction of a simple 'first step' cost-free technology to assist with translation on site seemed interesting and timely.

The research reported here, focused primarily on the Romanian sub-group of foreign workers, found that even though 85% of foreign workers interviewed on the sites face

language barriers daily, 50% of them have no interest in learning English. The areas most affected by the language barrier were found to be SIP and the basic on-site communication between managers and workers. As the workers could not understand the simplest of instructions, basic communication of tasks usually involved the workers going to get the assistance of workers who had better English. Suggestions by those interviewed to overcome the language barrier included the availability of a translator and the provision of safety / site videos in foreign languages, both of which would have both logistical and financial implications for the contractor. The availability and use of, Google translate as an assistive technology, despite some limitations, could reduce the negative impact of the lack of English-speaking ability, as a cost-free first step in reducing language barriers on site.

To investigate the effect, simple tests were carried out where the instructions were given in written format or verbally, with and without access to the Google Translate app on a smartphone. The findings indicate that the use of the Google Translate app, available free on both Android and Apple platforms, allowed the workers receiving instruction to understand the instruction and complete the task correctly and promptly, without any need to seek help with the English. This meant that the workers were not only more productive but were also safer when they understood the task. Thus, despite its limitations as listed earlier, Google Translate could be a useful tool for communication with non-English-speaking foreign nationals when giving instructions or during induction. The barriers to implementation of Google Translate as an assistive technology are minimal as everyone on site has a smartphone and the application is free to download.

The possible future research for this topic would be analysing in detail: how much time could be saved on site, the difference in the number of accidents/fatalities on site if Google Translate is used effectively and measuring the reduction in the amount of rework done by reducing the language barrier.

More work would need to be done in terms of how technologies associated with BIM such as augmented reality through the use of helmets with visors that present workers with translated instructions, could influence productivity, quality and H&S on site. This is of course dependent upon having the system tuned to the translation process, managers and professionals who can structure the instructions or information in the correct way, the availability of the technology for workers who have sufficient experience to understand the instruction and the skill be able to implement it.

In conclusion, the positive effects of using Google Translate on-site could go some way in making foreign workers more effective and productive while enhancing site safety for themselves and everyone else on site.

REFERENCES

Antwi-afari, M F, Li, H, Wong, J K-W, Oladinrin, O T, Ge, J X, Seo, J-O, Wong, A Y L (2019) Sensing and warning-based technology applications to improve occupational health and safety in the construction industry: A literature review, *Engineering, Construction and Architectural Management*, https://doi.org/10.1108/ECAM-05-2018-0188

Construction Helpline (2018) *English Not Your First Language? Here's How You Can Take Your CSCS Test*, Available from https://www.constructionhelpline.com/cscs/english-not-your-first-language-heres-how-you-can-take-your-cscs-test Mitcham, Surrey: Construction Helpline Ltd [accessed 25/09/2018].

Construction Industry Training Board (2011) 'Migrant construction workers and Health and Safety communication' Available from https://www.citb.co.uk/documents/research/migrant-construction-workers-health-safety-communication_tcm17-25018.pdf [accessed 20/09/2018].

Edirisinghe, R (2019) Digital skin of the construction site: Smart senor technologies towards the future smart construction site, *Engineering, Construction and Architectural Management*, 26(**2**), 184-223.

Health and Safety Executive (2018a) *Advice for Employers*, Available from http://www.hse.gov.uk/migrantworkers/employer.htm [accessed 12/10/2018].

Health and Safety Executive (2018b) *Construction*, Available from http://www.hse.gov.uk/migrantworkers/construction.htm [accessed 14/10/2018].

Health and Safety Executive (2018c) *Research*, Available from http://www.hse.gov.uk/migrantworkers/research.htm [accessed 25/10/2018].

Koseoglu, O, Nurtan-Gomes, E T (2018) Mobile BIM implementation and lean interaction on construction site: A case study of a complex airport project, *Engineering, Construction and Architectural Management*, 25(**10**), 1298-1321.

Loosemore, M and Andonakis, N (2007) Barriers to implementing OHS reforms - The experiences of small subcontractors in the Australian Construction Industry, *International Journal of Project Management*, 25(**6**), 579-588.

Loosemore, M and Lee, P (2002) Communication problems with ethnic minorities in the construction industry, *International Journal of Project Management*, 20(**7**), 517-524.

Office for National Statistics (2018) *Migrant Labour Force Within the Construction Industry: June 2018*. Available from https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/internationalmigration/articles/migrantlabourforcewithintheconstructionindustry/2018-06-19 [accessed 2/11/2018].

Rodrigues C (1996) *International Management: A Cultural Approach*. USA: West Publishing Company.

Trajkovski, S and Loosemore, M (2006) Safety implications of low-English proficiency among migrant construction site operatives, *International Journal of Project Management*, 24(**5**), 446-452.

Trotto, S (2016) *New Workers, Higher Risk*. Available from https://www.safetyandhealthmagazine.com/articles/14053-new-workers-higher-risk [accessed 29/09/2018].

CHALLENGING STANDARDISATION BY EMBRACING AMBIGUITIES OF SITE SAFETY: THE CASE OF MICRO CONSTRUCTION FIRMS

Emmanuel Aboagye-Nimo[1] and Ani Raidén[2]

[1] *School of Architecture, Design and the Built Environment, Nottingham Trent University, 50 Shakespeare Street, Nottingham NG1 4FQ, UK*

[2] *Nottingham Business School, Nottingham Trent University, 50 Shakespeare Street, Nottingham NG1 4FQ, UK*

Streamlining and standardising safety practices in the construction industry has always been the goal of many policymakers and large construction firms. This would understandably ensure that all practices on a wide range of projects adopt and implement similar procedures and regulations. In addition, this idea could possibly reduce the uncertainties and variations associated with interpretations of policies and regulations amongst project teams. Unfortunately, safety issues on construction projects and sites are widely acknowledged to differ from project to project and even activity to activity. For this reason, the implementation of a broad-brush approach has always proven difficult in the industry. Micro firms in the industry operate under the notion that projects and site conditions are always fluid and adapt their safety practices accordingly. The aim of this research is to the experiences and nuances in practices of workers of micro firms as they challenge standardisation by embracing ambiguities in project risks. Ethnographies were carried out on six construction sites in the South East and the East Midlands regions of the UK. Data collection tools adopted included observations, semi-structured interviews and conversations with tradesmen of selected micro firms. Findings from the ethnographic studies indicate that workers from small and micro firms from both regions acknowledge that the risks and hazards associated with various stages of projects change constantly. These changes are attributed to various reasons including site conditions, project changes, workers' state of mind and overall site culture. Furthermore, the workers believe that standardising approaches for all projects will be ineffective especially if the teams should encounter extenuating circumstances that they have not planned for. The workers thus embrace the uncertainties in safety and adopt an approach the considers the ambiguities associated with construction practices thereby being able to use a dynamic approach to avoid accidents and injuries that could prove costly or fatal.

Keywords: ethnography, micro firms, safety ambiguity, site safety

INTRODUCTION

The construction industry has always edged towards standardisation of practices for numerous reasons including productivity (Gibb, 2001; Pheng and Meng, 2018) and better work quality (Love *et al.,* 2000; Rumane, 2017). Although this is not a problem in the wider context, this can create problems when workers have to adapt to processes or situations that have not been captured in the standardised policies and

[1] emmanimo@hotmail.com

Aboagye-Nimo, E and Raidén, A (2019) Challenging Standardisation by Embracing Ambiguities of Site Safety: The Case of Micro Construction Firms *In:* Gorse, C and Neilson, C J (Eds) *Proceedings of the 35th Annual ARCOM Conference,* 2-4 September 2019, Leeds, UK, Association of Researchers in Construction Management, 546-555.

practices e.g. some project safety risks. The aim of this paper is to shed light on the experiences and nuances in practices of workers of micro firms (employing less than 10 workers) (European Commission, 2003) as they challenge standardisation by embracing ambiguities in project risks. The paper also delves into the taxonomy of team functions by exploring existing models and how overall safety can be improved using dynamic approaches. Subsequently, an explanation of the concepts of ambiguity and risks in construction projects is presented by considering how teams adapt to project complexities and inherent risks.

LITERATURE REVIEW

Construction projects are widely known for their complex nature from inception to completion. With these complexities arise numerous ambiguities particularly within communication and interpretation of risks (Floricel *et al.,* 2011). The literature review focuses on ambiguity and its role in construction safety practices.

Ambiguity and risk

The concepts of risk and ambiguity are connected in most construction works and require critical consideration for the success of projects (Walker *et al.,* 2017). Ambiguity is the '*perceived insufficiency of information regarding a particular stimulus or decision context*' (Acar and Göç, 2011: 842), in this case, risk and safety. Going by the Ellsberg Paradox; it is well established that people favour known probabilities in several instances including risk aversion (see Ellsberg, 1961). However, the complex realm of construction projects presents numerous situations that result in ambiguities and as such it is very difficult to identify every risk probability (Luo *et al.,* 2017). Risk by definition is the chance that individuals could be harmed by hazards (known and unknown) in conjunction with an understanding of how serious the harm could be (Health and Safety Executive (HSE), 2019). Small and micro construction firms are more tolerant of ambiguity and risk (Acar and Göç, 2011). This results from their relatively fewer formal practices and more importantly, their openness to the everchanging dynamics on site (ibid).

This research does not seek to offer a discourse on the differences between ambiguity and risk but rather accepts that the two concepts are interrelated in the context of safety practices. Furthermore, it is acknowledged that while a given risk remains objective, the different interpretations of the situation and the approaches of resolving the situation is open to different methods (subjectively). Even formalized and explicit safety policies of large firms will interpret risks differently before recommending strategies to manage them. Thus, it is argued that every firm or team regardless of size, approaches risks and their associated ambiguities differently.

Team Adaptability and Safety Practices

Teamwork and adaptability are crucial to the safety of workers and their surroundings. Salas *et al.,* (2008) identify three types of team competencies required for success: knowledge (cognition), attitude (feelings), and skills (behaviours). The above traits will inform the empirical phase of this study in an attempt to further assess the effectiveness of the safety practices of the teams included in this study. In dynamic work environments such as construction sites, workers will have to possess the quality of adaptability for success in safety and a successful project overall.

Adaptability involves the redistribution of tasks and workload among team members to achieve balance during high-workload or time-pressured situations (Burke *et al.,*

2006). Working teams not able to work to such standards may struggle to be efficient and thus less successful. Successful adaptation requires anticipation and recognition (Malakis *et al.,* 2010). As implied previously, workers must be able to anticipate risks (embrace ambiguity) in a dynamic setting in order to appropriately manage them.

Stagl *et al.,* (2006) offer a comprehensive framework on how working teams adapt to unique situations and more importantly, they show the key traits and characteristics that ensure these teams are successful in their adaptability. Figure 1 shows that individuals, teams and job characteristics shape the emergent cognitive and affective states of the projects. This then results in the dynamic processes of situation assessment and decision-making for the plans to be executed. Furthermore, it is very important to note that team situation awareness and a shared common mental standpoint is imperative to shaping the overall team adaptive performance. Team adaptation as a process is iterative thereby feeding into each other and thus workers learning from each situation or encounter (see Figure 1).

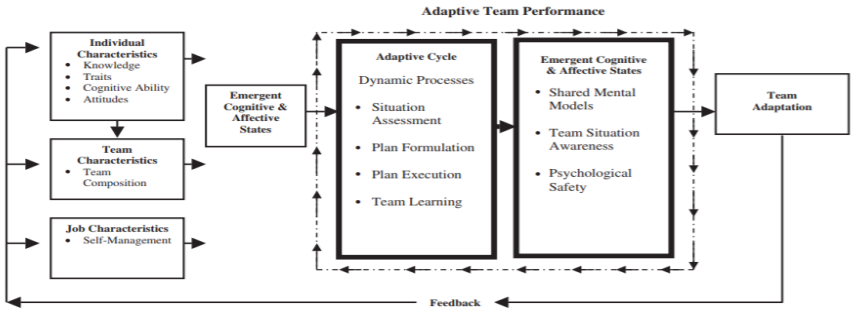


Figure 1: Heuristic Framework of Team Adaptation (Stagl et al., 2006)

A further analysis of Figure 1 indicates that some of the processes can be presented explicitly but other aspects may be more implicit. For example, situation assessments and plan formulation/execution can be included in the risk management process but other aspects such as individual attitudes may be more fluid within a given culture. After the critical consideration of the conceptual components of safety including ambiguity, risk and team adaptability; the next section presents literature on risk management practices amongst micro firms.

Risk Management Practices of Micro Firms

Smaller construction teams are known for their fewer formal approaches in practice including safety (Acar and Göç, 2011; Allison and Kaminsky, 2017). Pinder *et al.,* (2016) explain that the bureaucratization of the safety policies puts smaller teams at a disadvantage as they are known to adopt informal methods regarding safety. Practical knowledge and judgement on site require complex interaction of both explicit and tacit knowledge gained through training, experience, guidance by leaders, experiential learning in new situations, and from experts and experienced workers who have preceded the workers (Gherardi and Nicolini 2002, 192). Smaller teams including micro firms do not dismiss explicit practices although they tend to work through such formal approaches due to necessity and also if their resources allow for it. For example, formal safety policies may not be written down even though the workers may be adopting practical measures to ensure safe working environments for all. The bureaucratization of safety policies has gained a negative image as it burdens workers unnecessarily and hinders overall productivity (see Lord Young of Graffham, 2010; Cook, 2015). Bureaucracy and red tape prevent experienced and knowledgeable workers from using their knowledge gathered from years of experience in enhancing

site safety (Vassie *et al.,* 2000). The taxonomy of team functions is discussed next with a critical view on key areas such as communication, coordination and measures for error checking.

Taxonomy of Team Functions

Successful safety practices are based on effective communication, teamwork, accountability and responsibility and finally, monitoring practices. These features can all be found in the HSE's guidance notes for acceptable safety policies and practices (HSE, 2019). According to McGlynn *et al.,* (1997) the [United States of America] military adopts similar functions amongst individuals and make provision for interchanging roles based on the assessment of immediate conditions and surroundings (see Table 1). It is worth noting that practices of micro construction firms are not necessarily comparable military practices. However, it is suggested that the principles identified by McGlynn *et al.,* (1997) regarding team functions bear similarities to the approach adopted by construction firms (micro or otherwise). One important difference for micro construction firms is the lack of formal documentation. The above shall be explored further in the empirical phase. Similar to the everchanging events on construction sites, soldiers in the field adapt their practices when the situations change or evolve. This thus ensures their readiness for ambiguity relating to emergent and unknown risks. Readiness for ambiguity helps address aspects of work that may not be captured in prior risk assessment e.g. suddenly exposed live wire on site. Site workers must rely on their extensive experience and sense of awareness to manage such risks when they arise (Whiteoak and Mohamed, 2016).

Table 1: Taxonomy of team functions (McGlynn et al., 1997)

Information exchange	Includes information regarding member resources and constraints, team tasks and goals or mission, environmental characteristics and constraints, or priority assignment among subtasks
Coordination	Includes coordinating responses with task timing requirements or with responses of other members, including activity pacing, response sequencing, and time and position coordination
Assigning roles and responsibilities	Includes the need for role interchange and is the matching of information, numbers, etc., to subtask requirements
Error checking	Includes the process of monitoring individual and team activity, identifying problems, and adjusting team and member activities in response to errors and omissions or the attainment or lack of attainment of standards of performance

McGlynn *et al.,* (1997) highlight the importance of team functions with respect to eliminating errors; in the case of this study a means of ensuring workers' safety. Bureaucratic measures in construction can often hinder the ability of workers to be able to adapt their practices during situations of ambiguity and emergent risks and this can thus create more safety concerns when such situations emerge. Pheng and Fang (2005) identity aspects that construction projects could be more successful if they learn from other sectors (particularly team functions) e.g. effective communication - one of the most important elements of safety (see Kines *et al.,* 2010). This is in line with McGlynn *et al*'s (1997) discussion on taxonomy of team functions.

RESEARCH METHOD

Rapid ethnographies were adopted for this study. In this approach, open-ended interviews and explorative observations are replaced with condensed equivalents which are more focused on specific propositions and/or issues of interest which are identified from existing theory and literature before the research begins (Baines and

Cunningham 2013). In this instance, data collection can be carried out in a span of a few days. The ethnographies were conducted on four sites in the East Midlands and two in the South East region of the UK with each one lasting up to two days. Some of the micro firms studied were working as the sole contractors on some projects while other micro firms were working as subcontractors on larger projects. This offered a variety of views and a better understanding of the different situations that some micro firms may find themselves in. The research design helped generate a better understanding of the participants' cultural formation and negotiations, generation of inequalities (if any), labelling of deviance and other significant sociological processes in the given contexts (see Riain, 2009).

Data collection was undertaken through audio recordings and field notes. All site access was negotiated through gatekeepers as micro firms are generally known to be closed off to outsiders. As part of the ethical considerations of the project, pseudonyms were adopted for all participants presented in this paper. Although narratives and observations presented in this paper do not cover all the participants observed and interviewed, it is important to note that all interactions, observations and encounters on site helped shape the data presented in this study. The unit of analysis adopted for this study is a group approach i.e. micro firms and teams were considered as collective units on the various sites. This further helped in the understanding of the workers' approach to safety matters on their projects. A thematic analysis was conducted after a verbatim data transcription. This was followed by a preliminary analysis of the field notes, and this informed the manner in which the findings are presented next.

FINDINGS AND ANALYSIS

The main themes identified were in relation to workers' views on standardised practices, acceptance of ambiguity, equal opinions, and their fear of a lack of inclusion of their views in safety policies particularly when drafted by large main contractors.

Questioning Standardised Practices

A critical look at the research findings reveals standards or standardised practices can be either formal or informal. Formal standardised practices are written out explicitly in the form of organisational practices and policies and are less likely to contain ambiguity in their interpretation. Lacking ambiguity however does not necessarily imply the documented policies are always accurate. When micro firms work as subcontractors, they are obliged to follow main contractors' explicit rules. These rules are often blanket rules as they ensure uniformity amongst workers' practices all around. In addition to ensuring uniform working practices, this is also a crucial method of ensuring an effective span of control without assigning individuals to micro manage teams. For example, the *5-point PPE* (personal protective equipment) rule is widely adopted on most major construction projects regardless of outcomes of specific risk assessment practices.

Subcontractors agree that they *have to* follow the rules without fail even though they disagree with some of these policies.

Regarding the use of the 5-point PPE, Pete shares his concern about *'blindly*' conforming to these standards and even admitted he had gone against the rule in the past due to safety concerns. In a conversation with his colleague, they both agree that gloves had created concerns for safety for them in the past. *"I've come across that myself. It's annoying. You're doing something, and you have to take 'em off" - Mick*

It is worth noting that Pete's description of the situation as annoying can easily be misinterpreted as mere displeasure, but the wider context of the conversation reveals that he is referring to gloves creating unsafe situations - a situation that is agreed by his colleagues. Pete further explains that the standards are ideally developed to help workers but when they are not designed for specific tasks, it essentially invalidates the project's good safety practices. Although the removal of the gloves during any activity goes against the main contractor's policy, it is not 'wrong' according to the HSE guidance notes: "…*about identifying sensible measures to control the risks in your workplace*". Thus, an interim assessment of impending or newly developed risks inform Pete that the gloves would rather create a hazardous situation not prevent one. Other workers from different sites believed that standardised safety policies offered no flexibility or allowance. It was also widely acknowledged that many site managers disagree with blanket rules on health and safety issues, but they are pressured by the *"[writers] of these policies who are not in the best positions to understand the actual works" (John)* carried out by skilled tradesmen.

One key requirement of every effective safety policy according to the HSE (2019) is the creation of a safe space for workers to openly express and communicate any safety concerns. From the above interactions, Pete and his colleagues did not believe they were working in an environment that encouraged open communication amongst workers especially from subcontractors to main contractors. Furthermore, it is widely documented that challenging standards and policies of main contractors (including matters relating to safety) have in the past resulted in some subcontractors being placed on blacklists or quite ironically being excluded from main contractors' approved list of subcontractors (see BBC, 2016).

Embracing Ambiguity

Many workers on sites visited believed the construction practice in general was inherently dangerous and there were different ways of approaching the risks. Experienced workers and leaders showed genuine openness to listening to other workers about approaches to eliminating and/or minimizing risk on site. They believed that no matter your experience, you could be faced with a situation that you may not be equipped with the most efficient solution to manage it.

> There's always more than one way of doing something as well as several safe and unsafe ways as well. I think it's always good to discuss as well as just have your own opinion. Tony

Tony who had many years of experience and was the owner of his micro firm indicated he was willing to listen to the workers (both experienced and less experienced) because it was a good learning opportunity that could offer a new way of carrying out activities safer. Thus, he is in continuous search of improvement in their team's safety approaches. New risks and hazards could always lead to an opportunity to improve. Furthermore, new workers or new team members could mean an opportunity to gain a fresh perspective on the risk management. Therefore, the ambiguity they embrace is not always focused on the risk that arises but also the potential for a team member to offer a better solution to the impending issues.

In other instances when firms were working with main contractors, they had to be cautious of the supposed explicit and efficient safety measures. Even having been told about the formal risk assessment and risk control measures (which are supposedly not

open to negotiation thereby not ambiguity), workers still use their personal judgement to quickly assess situations to ensure their personal safety i.e. the workers still anticipate ambiguity and hence are prepared. The notion of embracing ambiguity enables them to dynamically and appropriately adapt their practices without the encountered situation significantly impacting the work flow or productivity. For example, Sam had his concerns about accepting all formal documentation on face value. *"I've been told before in the past like oh there's nothing live in there you can dig away and they added they had scanned the area as well (up north). Yeah you can dig away, but we start digging away and next minute there's a cable." Sam*

The key observation about when this story was told was that Sam was not surprised. His expectation of the unexpected meant he was prepared. According to McGlynn *et al.,* (1997) this function is referred to as 'error checking' in the military. A practice that Sam had not been formally taught but his years of experience has informed him that human errors do occur, and they fall under the category of risks and ambiguities.

Egalitarian Approach to Risk Management

Although there are both formal and informal hierarchies amongst micro firm workers, their approach to safety discussions did not reveal any power distances. Huang and Hinze (2006) highlight the role of the owner of the small team in shaping the safety culture. This current research does not dispute the above and it is further advocated that there is an egalitarian approach to safety negotiations among workers of micro firms. Owners tend to appreciate and incorporate the views of their workers/employees when arriving at decisions affecting safety.

An open conversation is the start of these negotiations. In a typical scenario where workers were trying to negotiate an approach to an emergent situation; workers were observed discussing whether an area could be classified as a confined space. The workers acknowledged the area in question was not the *'textbook definition'* of a confined space and as such were willing to discuss how they would define the situation and, how they would safely carry out their work there. The discussion involved both experienced and new workers. The experienced workers listened to the less experienced workers' views before proceeding to explain how the current situation posed more of a risk than they had envisaged. In the absence of this discussion, the less experienced workers would have attempted to carry out their task without the necessary emergent risk assessment and this could have led to an accident or injury. The point here is not the definition of the confined space but the opportunity the less experienced workers were given to share their views. This discussion was not formally documented. The workers have however demonstrated one vital point in a safety policy - effective and open communication which is a fundamental principle recommended by the HSE.

Another important observation was made when a team would always have tea and coffee in the morning in place of standard toolbox talks. They used this time create better communication amongst the workers and encourage a good relationship between experienced and less experienced workers. When asked about this practice, it was explained that it helps prevent rifts and power distances amongst workers. Furthermore, this was also known to help the less experienced workers develop as well as giving the older generations an opportunity to learn new approaches. Adam, the team leader with many years of experience stated the following:

> But you have got to communicate, you have to discuss opinions. What works better for me might not work better for them, so you've got to be prepared to discuss it and come to an accord some way that works better for you both. Adam

The above is in line with on-the-job learning processes of construction workers as they are allowed to learn through making mistakes with a clear explanation of why one view may be more effective (Gherardi and Nicolini, 2002) i.e. learning from mistakes.

Lack of Inclusive Policies on Projects

Most project safety policies are designed by the principal contractors as they are not done with the input of the workers of the micro firms who are usually subcontractors. The micro firms believe the policies and bureaucratic measures are only developed to prevent law suits and the worsening of the compensation culture.

When discussing the views of workers on various projects they had been part of, there were mixed views of how main contractors treat the subcontractors especially the micro firms.

> It's just basically the people you meet, some are a bit even and some are not, some you can communicate with and some just wanna do their job and don't wanna help you do your job. You're getting paid for it, so you do it. You know but you get some and you can talk to 'em and they might be able to advice you. George

George clearly believed many of the large firm workers were not happy to interact with his team let alone help them with tasks. This practice that George believes his team has been subjected to is unacceptable according to HSE regulations. Furthermore, not getting the necessary help one needs can lead to improper execution of activities which could then lead to accidents and injuries or poor work output. In addition, none of the workers included in the study had been involved in the development of the projects Construction Design and Management (CDM) documentation. By law, all parties must contribute to development of this document as it ensures every worker or site visitor's safety. The CDM regulations (2015) guidelines instruct that every project group or subgroup should have a considerable amount of input especially on matters affecting the tasks and activities they will be carrying out (Summerhayes, 2016).

CONCLUSIONS

This paper has explored an approach adopted by workers of micro construction firm workers when managing safety on projects. A rapid ethnographic approach was adopted to study the workers of these micro firms from within their operational setting. This approach enabled their everyday practices and interactions to be captured and analysed to sufficiently address the research aim i.e. highlighting the experiences and nuances in practices of workers of micro firms as they challenge standardisation by embracing ambiguities in project risks. Learning from established effective methods (see McGlynn *et al.,* 1997), the uncertainties and ambiguities associated with construction projects can be managed more efficiently if dynamic approaches are encouraged within the sector. Thus, the industry needs to acknowledge the existence of ambiguities and uncertainties in all projects and subsequently embrace a culture that readily adapts to address emerging risks. Role of workers in teams can interchange based on the developing events so as to enable a constant risk assessment and effective communication as projects are underway, thus workers can advise each other in relation looming risks and ambiguities in activities

and site conditions as they arise. This practice of adaptability will also ensure team members constantly monitor the safety of practices both individually and collectively.

This work is limited by the use of rapid ethnographies and it would be beneficial to policymakers, practitioners and academics if extensive ethnographies can be carried out on projects from inception to completion. This paper however sheds vital light on the importance of the industry's need to embrace practices that do not limit workers to standardised measurers but also encourage adaptability due to the nature of the industry.

REFERENCES

Acar, E and Göç, Y (2011) Prediction of risk perception by owners' psychological traits in small building contractors, *Construction Management and Economics*, 29(**8**), 841-852.

Allison, L and Kaminsky, J (2017) Safety communication networks: Females in small work crews, *Journal of Construction Engineering and Management*, 143(**08**), 1-8.

BBC (2016) *Construction Workers Win Pay-outs for 'Blacklisting'*, 9/05/2016. Available from https://www.bbc.co.uk/news/business-36242312 [Accessed 01/04/2019].

Burke, C S, Stagl, K C, Salas, E, Pierce, L and Kendall, D (2006) Understanding team adaptation: A conceptual analysis and model, *Journal of Applied Psychology*, 91(**6**), 1189-1207.

Cook, M (2015) From red tape to risk management, *Construction Journal*, 11-12.

Ellsberg, D (1961) Risk, ambiguity and the savage axioms, *Quarterly Journal of Economics*, 75, 643-669.

European Commission (2003) *Commission Recommendation of 6 May 2003 Concerning the Definition of Micro, Small and Medium-Sized Enterprises* (Text with EEA relevance) (notified under document number C (2003) 1422).

Floricel, S, Piperca, S, Banik, M (2011) *Increasing Project Flexibility: The Response Capacity of Complex Projects*. Newtown Square, PA: Project Management Institute.

Gherardi, S and Nicolini, D (2002) Learning the trade: A culture of safety in practice, *Organization*, 9(**2**), 191-223.

Gibb, A G F (2001) Standardization and pre-assembly- distinguishing myth from reality using case study research, *Construction Management and Economics*, 19(**03**), 307-15.

HSE (2019) Example risk assessments. Available from http://www.hse.gov.uk/risk/casestudies/index.htm [Accessed: 01/04/2019].

HSE (2019) Risk- Controlling the risks in the workplace. Available from http://www.hse.gov.uk/risk/controlling-risks.htm [Accessed: 01/04/2019].

Huang, X and Hinze, J (2006) Owner's role in construction safety, *Journal of Construction Engineering and Management*, 132(**2**), 164-173.

Kines, P, Andersen, L P, Spangenberg, S, Mikkelsen, K L, Dyreborg, J and Zohar, D (2010) Improving construction site safety through leader-based verbal safety communication, *Journal of Safety Research*, 41(**5**), 399-406.

Loosemore, M, Powell, A, Blaxland, M, Galea, N, Dainty, A and Chappell, L (2015) Rapid ethnography in construction gender research *In:* Raidén, A B and Aboagye-Nimo, E (Eds) *Proceedings of the 31st Annual ARCOM Conference*, 7-9 September 2015, Lincoln, UK, Association of Researchers in Construction Management, 1271-1280.

Lord Young of Graffham (2010) *Common Sense Common Safety*, London: Cabinet Office.

Love, P E D, Smith, J, Treloar, G J and Li, H (2000) Some empirical observations of service quality in construction, *ECAM*, 7(**2**), 191-201.

Luo, L, He, Q, Jaselskis, E J and Xie, J (2017) Construction project complexity: Research trends and implications, *Journal of Construction Engineering and Management*, 143(**7**), 04017019-10.

Malakis, S, Kontogiannis, T and Kirwan, B (2010) Managing emergencies and abnormal situations in air traffic control (part 1), *Applied Ergonomics*, 41(**4**), 620-627.

McGlynn, R P, Sutton, J L, Sprague, B L, Demski, R M and Pierce, L G (1997) *Development of a Team Performance Task Battery to Evaluate Performance of the Command and Control Vehicle (C2V) Crew*. Aberdeen Proving Ground, MD: US Army Research Laboratory (Contract No DAAL01-96-P-0875).

Pheng, L S and Fang, T H (2005) Modern-day lean construction principles: Some questions on their origin and similarities with Sun Tzu's Art of War, *Management Decision*, 43(**4**), 523-541.

Pheng, L S and Meng, C Y (2018) *Managing Productivity in Construction: JIT Operations and Measurements*. London: Routledge.

Pinder, J, Gibb, A, Dainty, A, Jones, W, Fray, M, Hartley, R, Cheyne, A, Finneran, A, Glover, J, Haslam, R and Morgan, J (2016) Occupational safety and health and smaller organisations: Research challenges and opportunities, *Policy and Practice in Health and Safety*, 14(**1**), 34-49.

Riain, S Ó (2009) Extending the Ethnographic. *In*: The SAGE Handbook of Case-Based Methods. London: Sage Publications, 289.

Rumane, A R (2017) *Quality Management in Construction Projects*. New York: CRC Press.

Salas, E, Cooke, N J and Rosen, M A (2008) On teams, teamwork and team performance: Discoveries and developments, *Human Factors*, 50(**3**), 540-547.

Stagl, K C, Burke, S, Salas, E and Pierce, L (2006) Team adaptation: Realizing team synergy, *In*: *Understanding Adaptability: A Prerequisite for Effective Performance Within Complex Environments*, London: Emerald, 117-141.

Summerhayes, S D (2016) *CDM Regulations 2015 Procedures Manual*. Chichester: John Wiley and Sons.

Sutton, J L, Pierce, L G, Burke, C S, Salas, E (2006), Cultural adaptability In: C S Burke, L G Pierce, E Salas (Eds.) *Understanding Adaptability: A Prerequisite for Effective Performance Within Complex Environments (Advances in Human Performance and Cognitive Engineering Research, Volume 6)*, London: Emerald Group Publishing Limited, 143-173.

Vassie, L, Tomas, J and Oliver A (2000) Health and safety management in UK and Spanish SMEs: A comparative study, *Journal of Safety Research*, 31(**1**), 35-43.

Walker, D H, Davis, P R and Stevenson, A (2017) Coping with uncertainty and ambiguity through team collaboration in infrastructure projects, *International Journal of Project Management*, 35(**2**), 180-190.

Whiteoak, J.W and Mohamed, S (2016) Employee engagement, boredom and frontline construction workers feeling safe in their workplace, *Accident Analysis and Prevention*, 93, 291-298.

INDUSTRIALISED CONSTRUCTION

ROBOTICS AND AUTOMATION AS A SOLUTION TO BRIDGING THE UK HOUSING GAP

Euan Fleming, Nicola Callaghan[1] and Nigel Craig

School of Computing, Engineering and Built Environment, Glasgow Caledonian University, Glasgow, G4 0BA, UK

The construction sector is reliant on manual labour for the completion of projects. Yet, low labour retention, skilled workers retiring at an alarming rate and falling numbers of graduates joining the sector are all adversely affecting construction capacity and output. Embracing the broader utilisation of robotics and automation is becoming more prevalent through technology-driven approaches such as the use of drones, autonomous machines, and 3D printers churning out new structures. Despite such technologies being considered a potential solution to improving productivity and efficiency, the uptake by the construction sector is not comparable to advances in other industries such as manufacturing and electronics. As a result, this research employs a mixed method approach consisting of 11 content analysis reports and 10 housebuilder surveys. The research aims to ascertain whether or not robotics and automation is being embraced by UK housebuilders, and in what form, and to what extent it is aiding in bridging the gap between current output and desired housing targets. The research indicates that automation is preferred over robotics, with large housebuilders predominantly leaning towards timber and steel frame solutions. However, several internal business conditions have to be met before widespread investment across the industry is likely. Criticism of the house building process, in terms of continuity between targets and local authority development plans, is recognised as a viable obstacle which currently prevents the sector from benefitting from modern technology.

Keywords: Automation, housing, labour, robotics

INTRODUCTION

The housing sector within the United Kingdom (UK) has a reputation for poor performance when compared to Government targets, which is currently set at 300,000 new homes per year (HM Treasury, 2017). However, since 1992 there have only been four occasions when this target has been achieved resulting in a chronic undersupply (HM Government, 2018). Despite Latham (1994) and Egan's (1998) attempts at promoting off-site manufacturing (OSM) in the form of pre-fabrication and modularisation as a way of increasing output, the industry has yet to fully embrace their proposals and have continued to under-deliver when compared to current housing targets. In line with work already carried out into the benefits of employing automation and robotics, this research explores whether or not the housing industry is already embracing or is preparing to embrace the change that is required to bridge the

[1] nca2@gcu.ac.uk

Fleming, E, Callaghan, N and Craig, N (2019) Robotics and Automation as a Solution to Bridging the UK Housing Gap *In:* Gorse, C and Neilson, C J (Eds) *Proceedings of the 35th Annual ARCOM Conference,* 2-4 September 2019, Leeds, UK, Association of Researchers in Construction Management, 557-566.

ongoing housing gap. In addition, an exploration into the factors that influence housebuilders decisions is also considered.

LITERATURE REVIEW

Poor productivity within the UK construction industry has been apparent for some time. The Department for Communities and Local Government (2017) provides evidence that the past 25 years has seen the UK economy's productivity grow by 41% while the construction industry has only experienced an 11% increase. When compared to other industries, the advantage construction had during the early 1990's no longer exists. There are several factors that contribute to low levels of productivity such as the fragmentation of the industry, the high number of smaller firms, an ageing workforce and the lack of investment in new technologies. Such new technology includes the use of robotics and automation which have been employed within a number of other industries and have demonstrated several benefits when compared to previous performances. However, the investment required for new technologies is significant and there has not been sufficient widespread investment which has led to fewer technological changes when compared to the likes of the automotive industry, consumer goods and home electronics (Fulford and Standing, 2013). Bogue (2013) advocates that as technologies have developed, the automotive industry has been able to use robots for more complex tasks while improving not only productivity but quality too. Michaels and Graetz (2015) concur that overall productivity and output gains can be made by employing automation on a number of tasks. However, given the complexity and uncertainty of construction, when focusing on output gains alone, measures that improve efficiencies may compromise the projects ability to be delivered effectively (Fearne and Fowler, 2006). Efficiency within the construction context is time-based and a measure of the relationship between organisational inputs and outputs which is inherent within robotics and automation (Quain, 2019).

Robotics and automated solutions have the potential to combat some of the existing issues as they can often work faster than traditional labour with comparable quality and no requirement for downtime. In an industry so focussed on health and safety and lost time accidents it is surprising that there has not yet been more interest in automation and robotics due to their potential to improve safety (Nawari, 2012).

Brick laying, for example, is a major part of the housebuilding process and is generally labour intensive to ensure precision and consistency. There are robotic innovations that have the ability to lay bricks such as the FastBrick: Hadrian series of robotics which is accurate to 0.5mm (Bock and Linner, 2016). In terms of productivity, a similar system known as SAM (Semi-Automated Mason) has the ability to lay 1,200 bricks a day compared with a manual workers average of 500 (Sklar, 2015). The benefits that robotics of this nature can bring to the construction industry, not only for their speed but for their quality, consistency and efficiency too, are clear. There have been similar developments of this nature in the past with Mahbub and Humphreys (2005) citing two UK based companies who developed masonry robotics in the late 1970's. While the technology of the 1970's would have been far less complex than today, it is interesting that the technology was not embraced 40 years ago; potentially preventing further development and thus widespread adoption in the current day.

Regardless of the condition of the site before construction, groundworks need to be carried out for levelling, piling or excavation. Currently, this is achieved through land excavators operated by humans. There have been developments in technology which

allow for these works to be carried out using the same excavators but with no need for an operator. Instead, the machinery relies on GPS which allows for an accuracy with 25mm. A main benefit would be the reduced likelihood of collisions/ incidents as the machinery is able to determine its position relative to others.

One particular area where publications disagree is whether robotics and automation will reduce the number of jobs within the industry. The International Federation of Robotics (2017) suggests that less than 10% of all jobs can be fully replicated by a robot but will result in the creation of wealth and opportunities elsewhere; while The McKinsey Global Institute (2017) suggest that the construction industry has the potential to employ automation on 47% of the tasks that are carried out. Berriman and Hawksworth (2017), on the other hand, argue that 30% of jobs (or 500,000) in construction will be at risk. In connection to the types of robotics discussed earlier, they are intended to be used alongside the labourer as they will be responsible for ensuring the robot operates with precision and quality. With humans and robots working in harmony there is the potential for fewer lost time accidents thus increasing productivity and output. As with any new technology there is likely to be investment required and construction robotics and automation will be no different. Ownership, or liability, could also be a potential issue with implementation. As there has been very little information gathered on liability of robotics it is hard to argue either way who may be responsible in the event of a failure; the manufacturer of the robot/automated machinery, the project manager, the person who logged the sequence or the individual overseeing its use. Kelley *et al.,* (2010) highlights that laws relate to the society that we live in today and so there has been very little consideration for human-robotic interactions. Until there is clarity on this issue it is hard to see developers adopting robotics on site. Compliance and insurance issues may also be a limitation to the widespread adoption of alternative solutions with Decker *et al.,* (2013) highlighting that there are extensive statutory, contractual, and performance-based requirements that must be satisfied in order for a project to be considered complete. With innovative methods, there may not yet be the necessary approvals and assurances in place that provide evidence that they are suitable for housebuilding which may influence the direction of all housebuilders.

METHODS

From a theoretical standpoint it is suggested that automation and robotics can positively influence productivity and output within the construction industry. As such, this research is concerned with identifying whether the housing sector is willing, planning or has already pursued alternative off-site, or indeed, on-site solutions in an attempt to meet housing targets and reduce the existing shortages. The research interprets a phenomenon (robotics and automation) on a personal level and uses this insight to develop an understanding of the bigger picture in practice. A phenomenological philosophy with inductive research has been utilised.

A mixed-method research approach was selected to understand the views and opinions of all sizes of housebuilders in the UK. Content analysis was used to assess qualitative publications from large housebuilders, meanwhile, a qualitative questionnaire was developed and circulated to SME housebuilders to gain an insight into their approach. However, while the source of data for this research is largely qualitative, which is in line with phenomenology, the results from each stage will be presented quantitatively with some qualitative aspects to contribute to the validity and understanding of the phenomena (McKim, 2017).

The first stage of the research was to undertake a content analysis using the computer program NVivo. The HMIR (2017) which ranks UK housebuilders, was used as a reliable source for selecting the top 5 large housebuilders. However, as several authors advise against solely relying on convenience sampling (Koerber and McMichael, 2008), an additional 6 housebuilders were determined using purpose sampling in an attempt to create a sample which truly reflects the approach of the top end of the sector. This approach reduces bias and maximises variation thus achieving a diverse study with a number of perspectives. As such, rank 7, 14, 20, 21, 23 and 25 were randomly selected. Annual reports are used by companies to showcase their excellence and performance and so are an ideal source of information relating to current projects and future plans. Table 1 summarises the housebuilder HMIR rank.

Table 1: Large Housebuilders Selected

Company	Rank	No of Homes Built
Barratt Developments Plc	1	17,319
Taylor Wimpey Plc	2	13,881
Persimmon Plc	3	15,171
Bellway	4	8,721
Berkeley Group	5	3,776
Galliford Try Plc	7	3,604
CALA	14	1,151
Kier	20	2,139
Keepmoat	21	2,416
Telford Homes	23	600
Avant Homes	25	1,210

To obtain an understanding of the documents, key words were queried with the corresponding results being assigned to a node. The text queries selected for this research were influenced by themes identified in the literature review and are summarised as; “Automation and Robotics”, “Housing of the Future”, “Innovation, Research and Development”, “Modern Methods of Construction”, “Off-Site Manufacturing, “Skills Shortage and Strategy” and “Government Housing Targets”. The intention of this stage was to identify common themes among large housebuilders with regards to the future strategy and approaches to delivering homes. In addition, it was hoped that it would identify positive advancements being made by large housebuilders in a bid to increase their output and efficiency. Secondly, the results can be used as a benchmark for assessing the approach of smaller housebuilders, therefore facilitating an understanding of the whole industry.

The rationale behind the questionnaire was to target small to medium size housebuilders to understand their viewpoint on automation and robotics. Saunders *et al.,* (2012) suggests that questionnaires are best suited in a method where there is at least one other type of data collection. As over 90% of firms in the construction industry employ fewer than 7 people (Office for National Statistics, 2017) gaining their perspective is essential in answering the research question. The samples gathered for the questionnaires relied on two methods. First was cluster sampling with the initial large group originating from the House Builder Federation Directory yielding 147 contacts. In an effort to gather a sample which represents locations throughout the UK, stratified sampling was used. The NHBC directory was consulted as it filters housebuilders by location. Samples were taken depending on the availability of contact information and a further 158 firms were selected resulting in a

total sample size of 305 SME housebuilders. All 305 questionnaires were distributed, 10 of which were completed, representing a 3.2% return rate. The low response rate perhaps suggests that SME housebuilders do not wish to engage in discussions surrounding automation and robotics.

RESULTS

The term "automation" showed in Taylor Wimpey and Barratt reports, respectively. The surrounding context suggests that Taylor Wimpey are considering several alternative methods with their focus being timber frame. Similarly, Barratt is developing automated solutions to improve speed and consistency; two of the many benefits of automation (Fulford and Standing, 2013). More results were expected but given the variety of names given to modern solutions it is no surprise there were only 4 results.

The sole reference to "robotics" was from Kier. The context of which is not directly related to housebuilding, but it does refer to using robotics to improve safety. As no other large housebuilder directly referenced construction robotics, it is a fair assessment that the application of on-site robotics is not yet at a stage where the industry is prepared to trial it. Nine out of ten questionnaire respondents said they had never heard of on-site construction robotics while the remaining housebuilder referred to a masonry robot being used in controlled trials. One of the respondents went on to suggest that "robotics will be the natural evolution of OSM assuming it proves to be an industry-wide success", but given that this was a minority view, it should not be taken as conclusive. Again, the application of robotics is possible in theory, as highlighted by The Mckinsey Global Institute (2017), but the many constraints to its application in the real world prevent it from being a feasible and widely available option for UK housebuilders. Six housebuilders referenced the term "future" with the majority being in the context of the direction of the organisation based on the use of different methods. A particularly interesting reference is from Galliford Try, "we see a strong future for on-site construction but there is a slow evolution towards manufacturing partly or wholly off-site". Galliford Try delivers over 3,500 homes yearly, which is approximately 2% of 2017 completions. If they have the finances to invest in OSM, but choose to not fully embrace it, it might suggest that there are other constraints that need to be satisfied before the industry can benefit from adopting OSM.

When asked about their thoughts on the industry's willingness to adopt new methods, there was overwhelming agreement that the industry is open to change. However, the biggest caveat to the widespread implementation of modern methods was that the technology had to be fully developed, compliant and financially beneficial. However, while this result may appear positive, the fact that OSM has been available for a number of years, yet it has taken until 2018 for it to be partially embraced may suggest that the industry is not as open to new methods as it thinks it is. With regards to future plans, 8 out of 10 returned questionnaires highlighted that housebuilders were planning on adopting more OSM in the future. "Innovation" gave the second highest frequency at 23 with almost 50% coming from Kier and the remainder from 5 other developers. The main focus appears to be finding innovative solutions to overcome persistent issues. Additionally, operational efficiency and safety were also key drivers behind the push for innovation. Investment in new technologies is costly, which the Government is aware of given their £205m planned investment in innovation. Kier has an estimated £30m R&D spend which will benefit their

operations and hopefully the rest of the industry in the near future. R&D is central to increasing the number of homes being completed and the UK Government is seeking methods to speed up the delivery of housing via a review of build rates. The National House Building Council (2018) states that 160,606 new homes are registered to start, up 6% from 2016 and the highest number since the start of the financial crisis in 2007.

"MMC" delivered 16 references from 6 housebuilders. Persimmon has the most references due to their investment in Space4, an MMC which "address three main challenges in housing delivery: Affordability, energy efficiency and construction industry skills shortage". Telford Homes referred to MMC as "an area of focus" and directly mentions the Government and how the industry is being encouraged to pursue modern methods. Barratt Homes discussed MMC trials including timber and steel frames. Both ends of the spectrum reported on MMC with Barratt Developments (Rank 1) and Avant Homes (Rank 25) making specific references. As large housebuilders begin to invest in MMC, it is possible to build up to four times as many homes with the same onsite labour required for one traditional build making it a potential solution to deliver the additional housing that is needed by the country.

"Off-Site" was referenced 20 times from 8 developers with Persimmon having 9 direct references. The results were able to identify some of the motivations for the large housebuilders to adopt off-site manufacturing. Interestingly, there was no mention of increasing output, instead, efficiency appears to be the biggest motivation. It may well be that increasing efficiency allows for more developments to be completed throughout the year thus leading to higher output. However, the housebuilders did not explicitly state this.

When asked about whether their organisation used any form of OSM, 7 of the 10 respondents said they had used it to varying degrees. The 3 which did not use it referenced insufficient output, cost and required finish as justification. The most common form was timber frame at 5 references, followed by prefabricated timber roofing (3), floor cassettes (2), light gauge steel frame (1), precast concrete foundations (1) and pre-fabricated bathroom pods (1). As identified by Fleming (2018), timber frame is competitive in terms of cost which may indicate why it is a chosen preference for SME housebuilders. Of all the MMC's available to SME's, CLT did not appear as a result. Given the reasons for adoption, it is perhaps not a surprise that this option is not a primary focus for SME's as it can be costly (Sutton and Black, 2011). While modularisation is an area of focus for large housebuilders, it would appear, from the results of the questionnaire, that SME's are less keen on the idea.

The consensus between the respondents appeared to be that using OSM was not for increasing output and there was no defined benchmark for them to judge their performance against. Further, the output of small builders varies year on year and so it is hard to solely attribute increased output to the use of OSM. Given the response to this question, there are concerns that the increase in output, productivity and quality demonstrated in other industries (Michaels and Graetz, 2015) may not translate positively to the housebuilding sector. Speed of construction was identified as the most prominent benefit, followed by quality, reduction in waste, H&S, planning and logistics, and cost. In terms of drawbacks, cost had the highest frequency with some discussion surrounding acceptance and compliance of OSM and logistical and planning issues. Taking both parts of the research together, it would appear that warranty and mortgage providers are wary of the use of new methods simply due to it

being different to tried and tested methods. The literature review introduced liability is a potential issue with the application of robotics (Kelley *et al.,* 2010) and so to a certain extent it would appear from the responses that a similar issue is present with particular MMC's. The trials carried out by large housebuilders will hopefully provide a level of assurance to not only SME housebuilders but other interested stakeholders too, providing the opportunity for new and innovative methods to be encouraged and welcomed. The UK Government has pledged its support to increase the use of offsite construction to help address the challenges. This commitment is reinforced by the House of Lords (2018) committee report into offsite manufacture which called for a radical overhaul of the construction industry in order to increase the number of homes being built.

This query gave the highest frequency at 42 with a total of 9 of the 11 large housebuilders referring to it. The term "shortage" was used within the context of housing and skills (labour), which is consistent with the figures and arguments presented by NHBC (2017), Farmer (2016) and Griffith and Jefferys (2013). There were a number of outputs following shortage which include the development of schemes for new employees in the industry as well as expanding on the extent of the housing shortage. Large housebuilders have the opportunity to invest heavily in skills and housing solutions and so the results from this query are positive. They suggest that large housebuilders are not only aware of the issues in the industry but are going to some lengths to tackle the problems related to all forms of shortage, which is in line with the recommendations made by Farmer (2016) and Barker (2004).

There was general agreement among the questionnaire respondents that sourcing labour was an issue. Only one of the respondents explicitly mentioned that they employ their own labourers and so it can be assumed that the rest of the respondents relied on sub-contracted labour. Interestingly, only half of the responses suggested that their organisation is addressing the skills shortage through the use of apprenticeship and graduate programmes. So, while they agree there is a skills shortage, not all of them are prepared to invest in order to overcome the problem. This may partially explain why the industry does not always achieve in encouraging young people to work in the industry and so perpetuates the issue of an ageing working population leading to poor productivity and output. This result is consistent with Farmers (2016) report which identified that while apprentice numbers are rising, the increase is not translating to more 16-19-year olds pursuing careers in construction.

The questionnaire asked SME housebuilders about their opinions of Government targets which gave a true insight into whether housing targets will ever be met. Of the 10 respondents, only one said its output was influenced by Government targets. There seemed to be a common theme among those sampled that business needs are the priority of housebuilders, rather than continually increasing the UK housing stock. 7 of the 10 respondents suggest that housing targets are nothing more than made up figures, with no clear linkages between Government targets, local council development plans and housebuilders. "There is often a lack of development due to council and local Government bureaucracy" (Respondent 2); "it would be foolish for us to dramatically increase our output to satisfy arbitrary Government targets" (Respondent 3); "...the Government really don't understand the housing industry and have not put in place any tangible measures to help developers meet that demand" (Respondent 5). Furthermore, it was evident that the industry is not structured to meet the demand and whist housebuilders would like to increase their output and turnover,

councils and local communities are wary of change which slows progression. "Government targets are ideals and are totally detached from reality. The Government wants X number of homes per year, but local councils can make it so difficult for developers to actually develop" (Respondent 7). It was also suggested that additional investment and support is required to encourage SME builders to increase their output. None of the housebuilders questioned mentioned the recent Government investment of £15bn for housebuilding or £204m for innovation and skills improvement; suggesting that A) they are not aware of it, B) they are not eligible to benefit from the investment, or C) there is no clear indication as to how the investment will directly benefit housebuilders.

CONCLUSIONS

The results of the content analysis are interesting as they show a focus towards off-site manufacturing and modern methods of construction, rather than robotics. It is clear that there are a number of options available and that the housebuilders are undertaking trials to determine which will best meet the needs of their business. It would appear that timber framing is at the forefront of the large housebuilders focus, followed by steel frame. However, one thing which is not clear from the analysis is the true motivation as to why housebuilders are investing and trialling new technologies. The results suggest that efficiency is a reason, but the issue remains as to what efficiency means to an organisation. There was no clear indication from any of the housebuilders that increases in efficiency on a particular development leads to more developments, and therefore more housing being completed. A similar assessment can be made from the questionnaire results. Timber framing appears to be the solution that small housebuilders are keen on adopting assuming it meets financial constraints and business requirements. Again though, the adoption of OSM is for no reasons related to dramatically increasing output. Further, the SME section of the industry has very little faith in the Governments targets to build 300,000+ homes per year and so will continue with their current approach of building a manageable number of homes that satisfies their business needs.

There were concerns from both samples that while OSM and MMC's bring several benefits, they cannot be fully realised at this point due to several constraints, some of which are brought on due to the current state of the industry while others stem from the fact that new methods are expensive and untested. While there was an increase in newly registered homes in 2016 of 6%, if SME builders do not have confidence that the targets are realistic then the industry will forever be set targets which cannot be met. It would appear from the research that large and small housebuilders are keen to build and invest but the landscape of the industry is not robust enough to support increases in development of up to 50%. The introduction of OSM, or in the distant future robotics, will potentially increase efficiency and reduce time spent on site, but if there are no possibilities of that gain being applied to starting another site then it is unlikely that output will ever significantly increase to meet targets. The current ideal of 300,000 homes per year is unrealistic with traditional methods and given the current development stage of modern solutions, it is unlikely that OSM, MMC's or robotics will contribute to bridging the gap in the near future either.

REFERENCES

Barker, K (2004) *Review of Housing Supply*. Available from http://news.bbc.co.uk/nol/shared/bsp/hi/pdfs/17_03_04_barker_review.pdf [Accessed 18/01/2019].

Berriman, R and Hawksworth, J (2017) *UK Economic Outlook: Will Robots Steal Our Jobs? the Potential Impact of Automation on the UK and Other Major Economies*. Available from https://www.pwc.co.uk/economic-services/ukeo/pwc-uk-economic-outlook-full-report-march-2017-v2.pdf [Accessed 12/01/2019].

Bock, T and Linner, T (2016) *Construction Robots: Elementary Technologies and Single-Task Construction Robots, Volume 3*. Cambridge: Cambridge University Press.

Bogue, R (2013) Robotic vision boosts automotive industry quality and productivity, *The Industrial Robot*, 40(**5**), 415-419.

Decker, H, Kasim, T, Nisbet, N, Rezgui, Y (2013) Towards Automated Compliance Checking in the Construction Industry, *In*: Decker, H, Lhotská, L, Link, S, Basl, J, Tjoa, A M (Eds.) *Database and Expert Systems Applications. DEXA 2013*, 8055, Springer, Berlin, Heidelberg.

Department for Communities and Local Government (2017) *Fixing Our Broken Housing Market*, Available from https://www.gov.uk/government/publications/fixing-our-broken-housing-market [Accessed 18/03/2019].

Egan, J (1998) *Rethinking Construction*. Available from http://constructingexcellence.org.uk/wp-content/uploads/2014/10/rethinking_construction_report.pdf [Accessed 23/03/2019].

Farmer, M (2016) *The Farmer Review of the Construction Labour Model: Modernise or Die*. London: Construction Leadership Council.

Fearne, A and Fowler, N (2006) Efficiency versus effectiveness in construction supply chains: the dangers of lean thinking in isolation, *Supply Chain Management*, 11(**4**), 283-287.

Fleming, H (2018) *Timber Frame*, Available from https://www.fleminghomes.co.uk/services-products/products/timber-frame [Accessed 18/08/2018].

Fulford, R and Standing, C (2013) Construction industry productivity and the potential for collaborative practice*, International Journal of Project Management*, **32**(2014), 315-326.

Griffith, M and Jefferys, P (2013) *Solutions for the Housing Shortage*. Available from https://england.shelter.org.uk/__data/assets/pdf_file/0011/689447/Solutions_for_the_housing_shortage_-_FINAL.pdf [Accessed 16/08/2018].

HM Government (2018) Permanent Dwellings Completed, by Tenure and Country. Available from http://opendatacommunities.org/data/house-building/completions/tenure [Accessed 16/12/2018].

HMIR (2017) *Housing Market Intelligence Report*. Available from https://www.house-builder.co.uk/publications/hmi [Accessed 22/06/2018].

HM Treasury (2017) *Autumn Budget 2017*. Available from https://www.gov.uk/Government/publications/autumn-budget-2017-documents/autumn-budget-2017 [Accessed 22/01/2019].

House of Lords (2018) *Off-Site Manufacture for Construction: Building for Change*. Available from https://publications.parliament.uk/pa/ld201719/ldselect/ldsctech/169/169.pdf [Accessed 10/06/2019].

International Federation of Robotics (2015) *The Impact of Robotics on Productivity, Employment and Jobs: A Positioning Paper by the International Federation of Robotics*. Available from https://ifr.org/img/office/IFR_The_Impact_of_Robots_on_Employment.pdf [Accessed 10/03/2019].

Kelley, R, Schaerer, E, Gomez, M, Nicolescu, M (2010) *Liability in Robotics: An International Perspective on Robots as Animals*. Reno: University of Nevada.

Koerber, A and McMichael, L (2008) Qualitative sampling methods, *Journal of Business and Technical Communication*, 22(**4**), 454-473.

Latham, M (1994) *Constructing the Team*. London: HMSO.

Mahbub, R and Humphreys, M (2005) An investigation into the barriers to automation and robotics in construction, *In: A* C Sidwell (Ed.) *Proceedings of the Queensland University of Technology Research Week International Conference*, 4-8 July, Brisbane, Australia.

McKim, C A (2017) The value of mixed methods research: A mixed methods study, *Journal of Mixed Methods Research*, 11(**2**), 202-222.

McKinsey Global Institute (2017) *A Future That Works: Automation, Employment and Productivity*. Available from https://www.mckinsey.com/~/media/McKinsey/Global%20Themes/Digital%20Disruption/Harnessing%20automation%20for%20a%20future%20that%20works/MGI-A-future-that-works-Executive-summary.ashx [Accessed 18/01/2018].

Michaels, G and Graetz, G (2015) Industrial robots have boosted productivity and growth, but their effect on jobs remains an open question. Available from http://blogs.lse.ac.uk/politicsandpolicy/robots-at-work-the-impact-on-productivity-and-jobs/ [Accessed 15/02/2019].

Nawari, N (2012) BIM standards in off-site construction, *Journal of Architectural Engineering*, 18(**2**), 82-101.

NHBC (2017) *NHBC New Home Statistics Annual Review Statistics*. Available from http://www.nhbc.co.uk/cms/publish/consumer/Media-Centre/Downloads/2017-Annual-Stats.pdf [Accessed 8/05/2018].

NHBC (2018) *New Home Figures Continue to Rise, Reports NHBC*. Available from http://www.nhbc.co.uk/media-centre/articles/statistics/february-april-2019/ [Accessed 3/06/2019].

ONS (2017) *Construction Statistics Annual Tables*. Available from https://www.ons.gov.uk/businessindustryandtrade/constructionindustry/datasets/constructionstatisticsannualtables [Accessed 23/01/2019].

Saunders, M, Lewis, P and Thornhill, A (2012) *Research Methods for Business Students 6th Edition*. Essex: Pearson Education Limited.

Sklar, J (2015) *Robots Lay Three Times as Many Bricks as Construction Workers*. Available from https://www.technologyreview.com/s/540916/robots-lay-three-times-as-many-bricks-as-construction-workers/ [Accessed 20/01/2019].

Sutton, A and Black, D (2011) *Cross Laminated Timber: An Introduction to Low Impact Building Materials*. Available from https://www.bre.co.uk/filelibrary/pdf/projects/low_impact_materials/IP17_11.pdf [Accessed 21/01/2018].

Quain, S (2019) *Organizational Effectiveness Vs Organizational Efficiency*. Available from https://smallbusiness.chron.com/organizational-effectiveness-vs-organizational-efficiency-22413.html [Accessed 10/06/2019].

CONSTRUCTION STAKEHOLDERS' PERCEPTIONS ON THE WIDER ADOPTION OF CONSTRUCTION AUTOMATION AND ROBOTICS: AN EXPLORATORY PRE-STUDY

Josephine Llale[1], Matleko Setati, Success Mavund, Thando Ndlovu, David Root and Paulin Wembe

School of Construction Economics and Management, University of Witwatersrand, Witwatersrand, Braamfontein, Johannesburg, 2000, South Africa

Rapid urbanization in developing countries (such as South Africa) is imposing strains on the current infrastructure project delivery models resulting in calls for structural changes in the socio-technical system of the construction industry. Automation and robotics have demonstrably improved the productivity in different industry sectors such as the automotive industry and mining, and there is growing interest in their application in construction. However, interest in their application in South Africa lags behind that of other countries, which may be due to the specific social, political, and economics circumstances of that country. This exploratory pre-study reports on the perceptions of South African industry stakeholders on the wider adoption of construction automation and robotics (CAR). Data is collected through semi-structured interviews with construction industry stakeholders. Thematic content analysis is used to analyse the results. The study considered the use of CAR as it relates to site activities in South Africa. The stakeholders' perception on the wider adoption of automation and robotics in South African sites is that the use of automation and robotics will result in permanent job losses. In a country, where unemployment is around 27,5%, the loss of jobs is undesirable and trumps other considerations such as quality and productivity. The South African urban infrastructure backlog can potentially be reduced by the use of construction automation and robotics. Wider adoption, however, will depend on stakeholder perceptions and socio-economic factors. Stakeholders in the construction industry in South Africa, particularly government, construction companies and labour unions will find the study beneficial.

Keywords: Automation, productivity, robotics, stakeholders

INTRODUCTION

WEF (2016) estimates that the urban population is increasing at a rate of 200 000 people per day. The increase in urban population puts a strain on the supply of housing and associated infrastructure in urban areas (WEF, 2016; Oke, Aigbavboa and Mabena, 2017). For instance, the housing backlog in South Africa is estimated at 2,1million (Engineering News, 2016). This backlog may be evidence that current infrastructure delivery models have reached their limits (Bock, 2015).

[1] 9205371p@students.wits.ac.za

Llale, J, Setati, M, Mavund, S, Ndlovu, T, Root, D and Wembe, P (2019) Construction Stakeholders' Perceptions on the Wider Adoption of Construction Automation and Robotics: An Exploratory Pre-Study *In:* Gorse, C and Neilson, C J (Eds) *Proceedings of the 35th Annual ARCOM Conference,* 2-4 September 2019, Leeds, UK, Association of Researchers in Construction Management, 567-576.

The automotive and mining industry have enjoyed the benefits of the use of automation and robotics such as increased productivity since their introduction (Bock, 2015). For instance, a bricklaying machine called Hadrian 105 can lay 1000 brick per hour in comparison to human labour at 100-200 bricks per hour (Shinde and Sarode, 2018). There is some merit, therefore, in inferring that wider adoption of automation and robotics in the construction industry will somewhat yield similar results as in those sectors and thereby potentially reduce the urban infrastructure backlog.

There are conflicting views on the impact of wider adoption of technology on jobs (Brynjolfsson and McAfee, 2014). Some authors claim that wider adoption of technology has the potential to result in job losses (Hager et al., 2016; Oesterreich et al., 2016). Others claim that the wider adoption of technology does not cause loss of jobs but a displacement of workers (Figueiredo, Pereira, and Dias ,2015; Clark, 1907 in Brynjolfsson et al., 2014). They claim that technology usually creates better work environment and better opportunities for workers. To perform in an automated environment, however, usually requires new skills (Ibid). Workers may require training (Ibid). It is in this transitionary period, of moving workers from unskilled jobs to skilled jobs that there seem to be job losses (Clark, 1907 in Brynjolfsson et al., 2014). In the long run new jobs are created (Ibid).

Given the conflicting views about the wider adoption of technology in workplaces, with one camp claiming that technology causes job losses and the other claiming that it creates better jobs in the long run, what are the perceptions of stakeholders in South Africa on this issue? With a huge urban infrastructure backlog and unemployment rate of about 27,5% (StatsSA, 2018a), South Africa finds itself in a quagmire. If claims that CAR results in job losses wider adoption of CAR in South Africa will be in conflict with the South African government's plan to reduce unemployment to 6% by 2030 (NPC, 2011) and is therefore undesirable. How will the South African government reduce the urban backlog without the wider adoption of CAR? If, however, the wider adoption of CAR causes temporary job losses, then there is potential for wider adoption in South Africa, which might result in the reduction of the urban infrastructure backlog.

The authors consider the perceptions of construction stakeholders as either a barrier or an enabler to the wider adoption of CAR in South Africa. It is for this reason that an exploratory pre-study was undertaken to determine what their perceptions on wider adoption of CAR in South Africa were. The paper, therefore, reports on the perceptions of construction stakeholders in South Africa on the wider adoption of CAR. Four industry stakeholders are interviewed, and a thematic content analysis is used to analyse the results.

LITERATURE REVIEW

Construction automation and robotics (CAR) can be divided into three categories; teleoperated systems, programmable construction machines and intelligent systems (Ardiny, Witwicki and Mondada, 2015). The classification of CAR depends on the extent of their interface with humans. Humans, for instance, control tele-operated systems, through the use of a remote control (Ibid). Programmable construction machines aid the human operator to perform certain tasks, "by choosing a pre-programmed menu or function or by teaching the machine a new function."(Ibid). Intelligent systems can operate without any human and are usually semi-autonomous or fully autonomous (ibid). In this study, CAR encompasses all the three categories of CAR as described by Ardiny *et al.,* (2016).

Literature list many benefits of the use of CAR on construction sites such as; 1) improved safety 2) enhanced quality 3) increased productivity, 4) a better work environment and 5) construction cost savings (Vähä, Heikkilä, Kilpeläinen, Järviluoma and Gambao, 2013). In this paper, the discussion on the benefits of CAR is limited to 1) improved safety and 2) increased productivity and efficiency. The authors have limited their scope of discussion within these confines because of South Africa's poor safety record on site and high urban infrastructure backlog, issues that could potentially be addressed by the wider adoption of CAR. Similarly, literature identifies a number of disadvantages in using CAR. Some of the disadvantages of the use of CAR include high investment and maintenance cost; limited capabilities, frequent change in CAR technologies and job losses ((Hager *et al.,* 2016; Oesterreich *et al.,* 2016). This paper confines the discussion on CAR's disadvantages to job losses only. The creation of jobs is a priority for South Africa. If wider adoption of CAR will result in job losses instead of the creation of new ones, wider adoption of CAR in South Africa might not be feasible. Hence, the discussion on this paper is concerned with potential job losses because of wider adoption of CAR.

One of the benefits of the use of CAR is increased productivity and efficiency (Oesterreich *et al.,* 2016). By using bricklaying robotics such as, Hadrian 105, the construction of a house can be completed in 1-2 days as opposed to several weeks or months (Shinde *et al.,* 2018). Contour crafting technology is another technological method that can supposedly complete a house within a few hours (Khoshnevis, 2004). Contour crafting is defined as," an additive fabrication technology that uses computer control to exploit the superior surface-forming capability of trowelling to create smooth and accurate planar and free-form surfaces" (Khoshnevis *et al.,* 2001 in Khoshnevis, 2004:2). Khoshnevis (2004) claims that a 200m2 double storey house can be completed in less than two days by using contour crafting. Improved efficiency is achieved through time saving and improved quality of work or product (Ibid). If South Africa is to reduce its infrastructure backlog, consideration should be given to the adoption of bricklaying robotics such as Hadrian 101.

The construction industry is known for its hazardous nature (Wang, Zou and Li, 2015). The International Labour Organisation (ILO) (2005:2) claims that "one in every six work-related fatal accidents occurs on a construction site". The number of incidences is high for small contractors (Cheng, Leu, Lin and Fan, 2010). Small contractors usually do not have the means to fully incorporate adequate safety measures on site (Ibid).

To train and create jobs for the unskilled, the South African government introduced the Expanded Public Works Programme (EPWP) (Skosana, Amisi, Maseko and Lukwago-Mugwera, 2016). EPWP, creates jobs through the implementation of labour-intensive project for certain public projects (DPW, 2015). Labour-intensive projects require, where appropriate, the use of unskilled workers in, for example, excavations not exceeding 1,5m deep, backfilling to trenches, and compaction of surfaces (Ibid). Funding for EPWP is from the government (Ibid). Contractors receive funds from government to pay the unskilled labourers.

Since its implementation, in 2004, EPWP has enjoyed some relative success in reaching some of its objectives. A cross sectional study done in 2011 revealed that over 80% EPWP participants were employed after participating in an EPWP (Henderson, 2017).

The implementation of labour-intensive construction project is largely carried out by small contractors in South Africa (McCutcheon, 2018). This is usually because high capital and maintenance cost are major barriers for the adoption of CAR (Oesterreich *et al.,* 2016). Small contractors, who are least likely to adopt CAR due to its high cost, usually resort to the use of labour to implement projects. Even though the use of labour by small contractors creates jobs on one hand, on the other hand it results in low productivity. In addition, some of the site activities that are dangerous and could potentially be carried out by CAR are usually carried by labour. Labour for a small contractor is, therefore, more at risk of incidents than for a big contractor. The continuing use of small contractor in carrying out construction somewhat addresses one socio-economic issue, unemployment, but it perpetuates two problems, poor safety and low productivity.

A study by Frey and Osborne (2017) of 702 jobs in the US revealed that low skilled and low wage jobs in the construction industry will be mostly adversely affected by the wider adoption of CAR. Through EPWP, the South African governments intends to create low skilled jobs in the construction industry. Wider adoption of CAR in South Africa may, thus, be at odds with the South African government's job creation objectives such as EPWP. Even though, there are claims from the proponents of wider adoption of CAR, that job losses by CAR are temporary and in the long term, CAR tends to create better jobs, there are doubts if this will indeed be the case (Brynjolfsson *et al.,* 2014). In a developing country such as South Africa, which imperatives should trump the others? Should job creation trump over safety and infrastructure delivery brought about by the wider adoption of CAR?

In light of these conflicting views from literature, the study wanted to answer the main research question "what are the perceptions of construction stakeholders on the wider adoption of CAR in South Africa? The premise upon which the main question of the study rest is that wider adoption of CAR in South Africa is ultimately dependent upon the stakeholders in the construction industry.

METHODOLOGY

Four stakeholders were interviewed to determine their perceptions regarding the wider adoption of construction automation and robotics in South Africa. Semi-structured interviews were chosen for they study as they allow for both rigidity and flexibility (Saunders *et al.,* 2016). Researchers were, therefore, able to ask predetermined questions without restricting the respondents' opinion and further contribution. Two major limitation of interviews are researcher's bias and participants' bias (Ibid)). Researcher's bias may arise in the framing of the interview questions and the interpretation of responses (Saunders *et al.,* 2016; Kumar, 2014). The participant's bias may arise where the participant withholds certain information (Saunders *et al.,* 2016). To mitigate both biases three of the authors of this paper conducted interviews with the participants. The same three authors analysed the data. This allowed for triangulation of the data (Creswell, 2014).

Purposive sampling method was used to select a researcher from a leading research organization in South Africa, a government official from a government department responsible for the implementation of public infrastructure projects, a safety officer from one of the top big 5 construction companies in South Africa and a representative from a workers' union. The benefit of purposive sampling is that participants are selected strategically (Bryman and Bell, 2014). Only relevant participants are thus selected for the interview (Ibid). The participants that were selected were deemed

relevant stakeholders in the construction industry in South Africa as they were most likely to be affected by the wider adoption of robotics.

After receiving ethical clearance from the relevant committee at the institution where the research was carried out, the authors sent email invitations to relevant individuals to participate in the study. Only four individuals responded. Geographic reasons and time constraints prevented more interviews to be carried out. The four stakeholders who responded are based in the Gauteng Province of South Africa and it is the same location where the researchers are based. The study formed part of the Honours degree which only gave researchers less than a semester to gather data. It is for these reasons that the four respondents were deemed sufficient. Gauteng Province is the most populous province in South Africa and the highest contributor to South Africa's gross domestic product (GDP) (StatsSA, 2018b, StatsSA, 2018c). Given the time constraints and that all authors are based in Gauteng, it was considered more expedient to interview the four stakeholders who responded to the invitation for the interview.

For anonymity the four stakeholders interviewed are identified thus; participant 1 is the government official, participant 2 is the safety officer from a contractor with a Construction Industry Development Board (CIDB) grading of 9, participant 3 is the mining engineer who is also a mine and construction labour union's representative and participant 4 is the researcher from a leading research organization in South Africa..

Participant 1 was selected based on the fact that government is the biggest investor in infrastructure and the government carries the greater responsibility of providing infrastructure in South Africa. The wider adoption of CAR might possibly assist the government in meeting its constitutional mandate.

A CIDB grade provides an indication of the value of construction work a contractor is deemed capable of performing within a certain class of works (CIDB, Not Dated). It is compulsory for a contractor who wishes to engage in a public sector project to apply for a CIDB grading (Ibid). Grade 9 is the highest score on the CIDB grading scale (Ibid). A grade 8 contractor can only undertake work whose value does not exceed R130m (Ibid). There is, however, no limit for a contractor with a CIDB grade 9 score (Ibid). Big contractors are more likely than small contractors to adopt CAR as CAR has high capital and investment costs (Oesterreich *et al.,* 2016) hence the inclusion of participant 2.

The union representative, referred to in this study as participant 3, is also a mining engineer involved in labour intensive activities in mining projects. Mining fatalities are high in South Africa. 88 fatalities were reported for 2017 (Minerals Council of South Africa, 2018). CAR is suitable for use in dangerous activities such as mining (Ardiny *et al.,* 2015). Soliciting the opinion of a mine representative meant, to some extent, understanding the perceptions of workers on the wider adoption of CAR in dangerous working environments.

Participant 4 was included because of the role research contributes towards change and innovation. Their opinion is most likely to be based on scientific research.

Data was analysed using thematic analysis. By using thematic analysis, qualitative data is analysed by searching for common themes and patterns across a data set (Saunders *et al.,* 2016). Thematic analysis was the preferred choice of analysis mainly because of its flexibility and its usefulness in understanding, "factors underpinning human attitudes and actions" (Saunders *et al.,* 2016:579). Eight common themes

emerged from the data set, they are; impact, construction robotics, observation, reading, experience, strikes, skills upgrade and efficiency.

FINDINGS

In this section, major findings from the interviews are summarised. The main research question of the study is," "what are the perceptions of construction stakeholders on the wider adoption of CAR in South Africa? Oke *et al.,* (2017) claim that CAR was introduced to achieve objectives that would otherwise be impossible without them. Technology was also introduced to improve safety and improve productivity and efficiency (Cottle, 2014). The main aim of the empirical study was to determine on which side construction stakeholders' perceptions in South Africa lay; on whether they believed that the wider adoption of CAR resulted in job losses or whether the it results in temporary job losses and the creation of better jobs in future. The study was also interested in determining where the perceptions stemmed from.

The level of impact that technology had on the participants' work environments

The first set of questions were intended to determine how the participants responded to the introduction of new technology within their work environment. Through these questions, the authors sought to determine whether the intended benefits of technology were realised and if the participants' perceptions on the wider adoption of robotics were borne from their personal interface with technology within their own work environment.

All participants expressed a positive disposition towards their work environments (refer to figure 1). None of the participants was negatively impacted by technology. Technology has improved their work by making their jobs easier, their response to technology was generally positive.

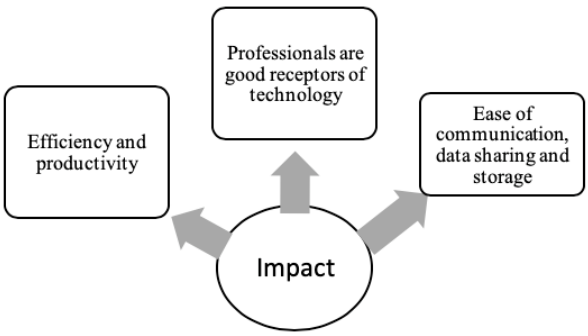


Figure 1: Participants' perceptions on technology in their own work environments

The wider adoption of CAR in South Africa

Participants were asked for their views on the wider adoption of CAR in South Africa. Questions asked sought to determine the participants' understanding of the relationship between CAR and employment. The participants are of the perception that a wider adoption of CAR will reduce employment in South Africa. Participant 3's response was that, "It will decrease the number of jobs. The disadvantages of adopting construction robotics or mining robotics is that they will take employment from people, simply. We cannot run away from the fact that machinery takes jobs from labour and worse part is when they are not assembled within the country". Participant 4's response was slightly different from the other three participants; his response was that "Introducing robotics in South Africa without raising skills level

would be catastrophic for employment. There should be a right balance to move workers to the digital economy." Thus, participant 4 acknowledged the need to train labour before wider adoption of CAR.

The source of the participants' perceptions

To establish where the participants' perceptions stemmed from, participants were asked questions relating to their personal interaction with CAR in their work experiences. All participants except for participant 3 had never had personal interaction with CAR in their work experiences. From the set of questions related to participants' perceptions, it seems like the participants' perceptions stem from television, the internet and construction related magazines.

Participant 1's perceptions seem to have largely been influenced by having watched, on television, a house being built solely by CAR;" I have seen that there is a machine that builds foam houses from excavations to the roofing." Participants 2 perceptions seem to stem largely from work experience and reading construction and related magazines. As a safety officer on construction site, participant 2, has had a real life experience of machinery replacing labour on site; "…I also have negative feelings about them because I think they behave the same way as construction machinery and even worse because they do not need operators like construction machines need. They will definitely eliminate jobs." Participants 4's perceptions were based on research, "but as a researcher I read general on technology…Robotics are topical in industry report, articles and journals."

Benefits of CAR

Participants were asked questions related to benefits associated with wider adoption of CAR in construction sites such as safety, efficiency and productivity. All participants agreed that the use of CAR on construction sites had a positive effect on safety, efficiency and productivity (see figure 2). The following are participants' 1 and 3 responses respectively, "there is no doubt that robots will improve productivity on construction sites…" and "I do not know about construction robotics, but, if the mining industry was to adopt the robotics and automate the activities, definitely productivity will improve to a greater scale compared to where it is today…"

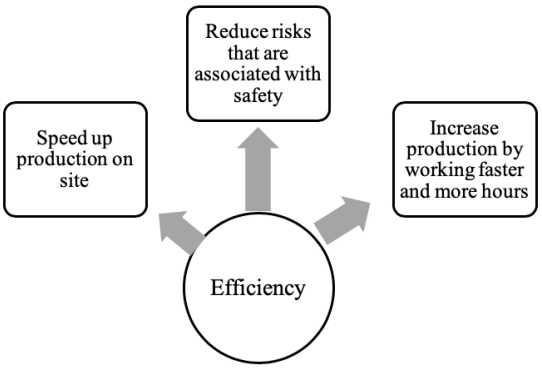


Figure 2: Participants' perceptions on the benefits of CAR

Other Possible Outcomes of Wider Adoption of CAR

Participants were asked questions related to possible outcomes of wider adoption of CAR in South Africa. One of the biggest threats expressed by participants on the

wider adoption of CAR was the fear of strikes. Participant 1's response was "…however, as mentioned before, with the current economic status of our country I don't see robots even operating on sites. Communities will revolt and ensure that no work is carried out on site." According to participant 2, "…Unions as well will suffer, leading to strikes, because if less people are employed, the unions will suffer since they will not be getting the income that they are earning when people are working." The views of participant 3 were "I think the industry may welcome it but labour will not, come on, remember I am a union representative, so I wouldn't welcome it too. There will be many strikes if they force it and yeah, those who will be affected the most will not love it." Participant 4 said that "...Such technology may fuel social tension and instability. It is therefore of critical importance that education and training keep pace with technology."

Summary of Findings

Even though all participants acknowledged that wider adoption of CAR will improve safety and productivity on site, the general perceptions of the construction stakeholders is that wider adoption of CAR will result in job losses. Only one participant, participant 4, indicated that wider adoption of CAR should be coupled with labour training. Participant 4's views stemmed mainly from credible sources such as industry articles and journals. The other participants' perceptions stemmed from media.

CONCLUSION

Literature reveals that there are many benefits to the use of CAR on construction sites, such as improved safety, better efficiency and increased productivity. One of the main disadvantages of wider adoption of CAR is job losses. There are, however, conflicting views on whether these job losses are permanent or temporary. This paper aimed at finding out what the perceptions of the South African construction stakeholders on wider adoption of CAR are, that is, whether they perceived wider adoption of CAR to cause temporary or permanent job losses.

The findings of this study reveal that the perceptions of the stakeholders are that CAR results in permanent job losses. The perceptions of the participants of this exploratory pre-study may be indicative of the general perceptions held by the majority of stakeholders whose perceptions may be based on unreliable sources such as media. If South Africa, chooses CAR to improve on safety and productivity on construction sites, educating construction stakeholders and labour may be necessary. To address the issue of job losses because of wider adoption of CAR, the industry might opt for teleoperated systems and programmable construction machines in the short and medium term as they allow for human interaction. Autonomous and semi-autonomous CAR may only be used in dangerous work environments in the short and medium term. The introduction of CAR must be coupled with the training of labour. Unless construction stakeholders including labour are educated on the advantages and disadvantages of CAR wider adoption in South Africa will continue to lag behind other developed countries.

Even though the findings of the study cannot be generalised, they can provide a basis for making propositions for future studies. This paper recommends that future studies should look at how wider adoption of CAR can create jobs in developing countries such as South Africa.

REFERENCE

Ardiny, H, Witwicki, S and Mondada, F (2015) Construction automation with autonomous robots: A review, *In*: *3rd RSI International Conference on Robotics and Mechatronics (ICROM)*, 7-9 October, Tehran, Iran.

Bock, T (2015) The future of construction automation: Technological disruption and the upcoming ubiquity of robotics. *Automation in Construction*, 59, 113-121.

Bryman, A and Bell, E (2014) *Research Methodology: Business and Management Contexts*. Cape Town: Oxford University Press.

Brynjolfsson, E and McAfee, A (2014) *The Second Machine Age*. New York: W W Norton and Company, Inc.

Cheng, C W, Leu, S S, Lin, C C and Fan, C (2010) Characteristic analysis of occupational accidents at small construction enterprises, Safety Science, 48(**6**), 698-707.

Construction Industry Development Board (Undated) About the RoC. Available from http://www.cidb.org.za/contractors/Pages/Register-of-Contractors.aspx [Accessed 05/04/2019].

Cottle, E (2014) *The Transformation of the Construction Sector in South Africa Since Apartheid: Social Inequality and Labour*, PhD Thesis, State University of Campinas, Brazil.

Creswell, J (2014) *Research Design: Quantitative, Qualitative and Mixed Methods Approaches*. Thousand Oaks: Sage.

Department of Public Works (2015) *Guideline for the Implementation of Labour-Intensive Infrastructure Projects Under the Expanded Public Works Programme (EPWP).* Pretoria: Government Printer.

Elattar, S M S (2008) Automation and robotics in construction: Opportunities and challenges, *Emirates Journal for Engineering Research*, 13(**2**), 21-26.

Engineering News (2016) Housing backlog at 2.1m, says Minister Sisulu. Available from https://www.polity.org.za/article/housing-backlog-at-21m-says-minister-sisulu-2016-04-22 [Accessed 04/04/ 2019]

Figueiredo, A E, Carvalhal, R D D, Hoeflich, S, Figueiredo, L, Pereira, S L and Dias, E M (2015) Port operation-increase of automated systems, decline of workforce Jobs? *Recent Advances in Computer Science*, 259-266. Available from http://www.inase.org/library/2015/zakynthos/bypaper/COMPUTERS/COMPUTERS-42.pdf Accessed 19/07/2019].

Frey, C and Osborne, M (2017) The future of employment: How susceptible are jobs to computerisation? *Technological Forecasting and Social Change*, 114, 254-280.

Henderson, S W (2017) Expanded Public Works Programme (EPWP) of South Africa (phase 3) The Expanded Public-Works Programme as a Catalyst for Work Opportunities, Growth and Development. Available from https://www.parliament.gov.za/storage/app/media/ProjectsAndEvents/2017_ncop_provincial_week_october/docs/EPWP_as_a_Catalyst_for_Development-Mr_Dladla.pdf [Accessed 7/12/2018].

International Labour Organization (2005) *Facts on Safety at Work*, Geneva: International Labour Organization.

Khoshnevis, B (2004) Automated construction by contour crafting-related robotics and information technologies, *Automation in Construction*, 13(**1**), 5-19.

Kumar, R (2014) *Research Methodology: A Step-by-Step-Guide for Beginners*. Los Angeles: SAGE.

McCutcheon, R (2018) EPWP projects have potential, I*nstitute of Municipal Engineering of Southern Africa Magazin*e, 43(**4**), 50-51.

Minerals Council South Africa (2018) *Facts and Figures*, Available from https://www.mineralscouncil.org.za/downloads/send/18-current/634-facts-and-figures-2017 [Accessed 5/04/2019].

Oke, A, Aigbavboa, C and Mabena, S (2017) Effects of automation on construction industry performance, *Advances in Engineering Research*, 102, 370-374.

Oesterreich, T D and Teuteberg, F (2016) Understanding the implications of digitisation and automation in the context of industry 4.0: A triangulation approach and elements of a research agenda for the construction industry, *Computers in Industry*, 83, 121-139.

Rotman, D (2013) *How Technology is Destroying Jobs*, MIT Technology Review Magazine, July/August 2013.

Saunders, M, Lewis, P and Thornhill, A (2016) *Research Methods for Business Students*. Essex: Pearson.

Shinde, V and Sarode, G (2018) Robotics application in construction industry, *International Journal of Engineering and Management Research*, 8(**2**)16-18.

Statistics South Africa (2018a) *Statistical Release P0211: Quarterly Labour Force Survey - Quarter 3:2018*, Pretoria: Statistics South Africa.

Statistics South Africa (2018b) If *South Africa's Provinces Were Independent States*. Available from http://www.statssa.gov.za/?p=11092 [Accessed 2/4/2019]

Statistics South Africa (2018c) *Statistical Release P0302: Mid-Year Population Estimates*, Available from https://www.statssa.gov.za/publications/P0302/P03022018.pdf [Accessed 2/4/ 2019]

Skosana, N, Amisi, M, Maseko, Z and Lukwago-Mugerwa, P (2016) *When a Stipend Puts Food on the Table*. Available from https://evaluations.dpme.gov.za/images/gallery/EPWP%20Policy%20Brief.pdf [Accessed 7th December 2018]

Vähä, P, Heikkilä, T, Kilpeläinen, P, Järviluoma, M and Gambao, E (2013) Extending automation of building construction - survey on potential sensor technologies and robotic applications, *Automation in Construction*, 36,168-178.

Wang, J, Zou, P X W and Li, P P (2016) Critical factors and paths influencing construction workers' safety risk tolerances, *Accident Analysis and Prevention*, 93, 267-279.

World Economic Forum (2016) *Shaping the Future of Construction: A Breakthrough in Mindset and Technology*. Available from http://www3.weforum.org/docs/WEF_Shaping_the_Future_of_Construction_full_report__.pdf [Accessed 02/06/2018].

MANAGING THE BENEFITS AND IMPEDIMENTS TO OFFSITE CONSTRUCTION IN THE UK CONSTRUCTION INDUSTRY

Saheed Ajayi[1], Jamiel Brinklow-Harris,[2] Hafiz A Alaka[3] and Jamiu A Dauda[4]

[1] *Leeds Beckett University, Northern Terrace, Queen Square Court, City Campus, Leeds, LS2 8AG, UK*

[2] *Focus Consultants, Focus House/Millennium Way West, Nottingham NG8 6AS, UK*

[3] *University of Hertfordshire, De Havilland Campus, Mosquito Way, Hatfield, AL10 9EU, UK*

[4] *School of Civil Engineering, University of Leeds, Leeds, LS2 9JT, UK*

The use of offsite methods of construction has long been recognised as a suitable method for increasing the supply of housing and addressing productivity in the construction industry. Whilst the literature is rife with the many benefits of the modern methods of construction as well as barriers to its implementation, its adoption remains relatively low. This study contributes to the discussion by investigating the strategies for further harnessing the benefits of the increasingly important method of construction as well as the measures for mitigating its challenges. In line with the tenet of phenomenological research, which seeks to explore the phenomenon from the perspectives of the industry experts, 12 interviews were carried out with construction professionals. The data were analysed using thematic analysis, thereby unravelling the emerging themes that emanated from the interviews. After identifying such benefits of offsite construction as increased built quality, waste mitigation, and time efficiency, among others, the strategies for maximising these benefits were presented. These include enhanced training, use of digital tools, standardisation of building components and more efficient pre-planning activities, among others. Similarly, impediments to the use of offsite construction techniques such as its high initial cost, negative stigma, non-supportive project delivery models and clients' resistance could be addressed through some measures. These measures include the development of new supply chain management model, training and education, enabling legislation and vertical integration within companies. This study will help to identify the measures for enhancing the adoption and implementation of offsite technologies in the UK construction industry. Future research is recommended to assess the government's role in being the driving force behind implementing prefabrication-specific policies and incentives to encourage its future use.

Keywords: prefabrication, off-site construction, productivity

INTRODUCTION

Offsite construction is increasingly gaining momentum in the construction industry because of the need for expedient delivery, technologically advanced as well as the renewed government backing (Siebert *et al.,* 2019). The objective of this is to deliver to the construction site, elements that are in an advanced state of completion, which remove substantial site activities from the construction process. Using offsite method,

[1] S.Ajayi@Leedsbeckett.ac.uk

Ajayi, S, Brinklow-Harris, J Alaka, H A and Dauda, J A (2019) Managing the Benefits and Impediments to Offsite Construction in the UK Construction Industry *In:* Gorse, C and Neilson, C J (Eds) *Proceedings of the 35th Annual ARCOM Conference,* 2-4 September 2019, Leeds, UK, Association of Researchers in Construction Management, 577-586.

buildings are manufactured offsite, assembled on site, and have the benefits of high project predictability, faster delivery, less disruption, less site accident rate, improved health and safety and less waste, among others (Goh and Goh, 2019; Smith, 2011; Ajayi *et al.,* 2015). Due to its many benefits, various government reports into construction productivity and housing supply, including Latham 94, Egan 98, Barker 2004 and Farmer 2016, have identified offsite technique as a critical enabler of the industry's productivity. However, there has been a reluctance to change within the industry that is known for innovation-bias and risk aversion (Sinesilassie *et al.,* 2017).

Although the concept of prefabrication, often referred to as offsite construction, modular construction, prefabrication and Design for Manufacturing and Assembly (DfMA), among others, has been in the UK since the 1950s (Harrison *et al.,* 2012), the primary production comes from smaller house builders who may build only a few hundred a year (Bury, 2017). The most notable early use of prefabrication in the UK is the housing made in factories built in significant quantities after WW2 to address the housing shortage. The Government used the factories previously used to make military equipment to produce the housing. At the time the homes were quite expensive, but due to the shortage of labour and materials, this was the only way to address the issue (Harrison *et al.,* 2012).

Meanwhile, the use of offsite techniques is increasingly becoming the industry standard in many nations. Countries such as Japan, Sweden, Germany and The Netherlands are pursuing this technology very seriously. 80% of detached housing uses prefabricated elements in Sweden, 40% of all apartments are prefabricated in Japan, 20% of new Builds in The Netherlands use these elements, and 9% of all new residential permits are for prefabricated buildings in Germany (Steinhardt and Manley, 2016). In the UK, it is thought that no more than 2% of construction work has any significant prefabrication (Steinhardt and Manley, 2016).

Literature is rife with the benefits of offsite construction as well as the barriers to its implementation (cf. Hong *et al.,* 2018; Pan *et al.,* 2008). Despite this promising nature of the construction technique, its level adoption remains disappointedly low. What the literature currently lacks is the direction on how to enhance the uptake of offsite construction. For instance, Killian *et al.,* (2016) identified the barriers and challenges to offsite construction but offered no solution for facilitating its adoption. Rahimian *et al.,* (2017) and Arif *et al.,* (2017) also identified the barriers and challenges to offsite construction without proffering solutions on how its hindrances could be addressed. While many studies identified its benefits (cf. Goh and Goh, 2019; Siebert *et al.,* 2019), there has been less focus on how such benefits could be maximised. By engaging the industry stakeholders, this study fills the gaps in the literature by identifying the strategies for maximising the many benefits of offsite construction as well as the approaches for minimising the barriers to its implementation. The benefits of offsite construction, as well as the barriers to its implementation, were identified and experts in offsite construction were then engaged to identify how to facilitate an improved use of offsite construction in the UK construction industry.

In line with the goal of this study, the next section presents a review of the literature on the benefits and barriers of offsite construction. The section is then followed by the presentation and justification of the methodological approach and the findings of the study, which is discussed before the paper culminates in the conclusion and implications of the study.

LITERATURE REVIEW

Goh and Goh (2019), among many other authors and practitioners, suggest that prefabricated components in comparison to onsite construction can achieve a better-quality product. This is due to better supervision as well as the associated quality assurance standard in a factory environment (Smith, 2011). Blismas and Wakefield (2009) found that prefabrication delivered better consistency, quality and component life while reducing whole life cost and defects. This is achieved through quality assurance in a controlled factory environment and the ability to use highly specialised equipment in controlled conditions. However, in a defects study undertaken by Johnsson and Meiling (2009), although there was an increase in quality, defects still occurred with 10% being linked to the lifting and transporting of the prefabricated components, including up to 2 years after the installation. These were directly linked to errors caused in the factory. As such, notwithstanding that quality is improved through the efficient use of skilled labour and machinery, proper attention must be paid to lifting and transportation, which could otherwise lead to defects and prevent superior quality associated with prefabricated components.

Another significant benefit of adopting prefabrication is the reduction of onsite construction time due to the possibility of simultaneously constructing in the factory while the onsite work is being done (Smith, 2011). Due to this, the required number of processes is reduced and simplified with the potential for time-saving, while also overcoming the possible impact the weather. In an example by Smith (2011), it is stated that a home was able to be built in a factory and then moved to the site and installed during conditions which would not have been suitable for traditional types of construction. Notwithstanding these benefits, Goodier and Gibbs (2007) noted that longer lead times could delay the beginning of the project, and to reduce this, the whole design and construction process needs to be more aligned. What this means is that even though time on site may be shortened as described by Smith (2011), what is not accounted for is any pre-planning and lead times to the use of prefabrication which may cause delays before onsite construction is started. Blismas and Wakefield (2009) also agree that on-site duration is shortened but argued that the usual estimation does not account for changes and knock on effects during production or onsite installation.

It is often argued that the cost of using prefabrication is often cheaper than the on-site equivalent. In line with this, Blismas and Wakefield (2009) suggest that prefab is a significant contributor to reducing whole life cost of construction through lower site related costs and earlier income generation for clients (Blismas and Wakefield, 2009). Prefabrication is widely believed to be capable on can achieving more productivity, and thereby reduces the cost of labour. However, some authors suggest that there are hidden costs that unaccounted when calculating the actual cost of the prefabricated units. A study carried out by Friedman (1992) considered 15 house builders in the Canadian market and their production of family homes. It was found that prefabrication was around 15% more expensive in comparison to traditional methods. This was due to the initial investment for a factory and the need to hire staff all year round. This is unlike the traditional method that only hires workers only when required. Smith (2011) also believes prefabrication is touted as being more cost-effective, and its cost is made up of 3 aspects - Material, Labour and Time - and in theory, a reduction in one will mean a reduction in costs. However, what is missed here and explained by Blismas and Wakefield (2009) is that prefabrication may suffer from an increase in design and transport cost if they are being transported over a long

distance. This implies that although prefabrication appears to be a cheaper alternative to traditional methods, but when considered further, many factors determine the cost.

In the industry that is well known for a high rate of fatality, prefabrication is perceived as a safer alternative to traditional construction. In a factory, processes can be carefully planned to minimise risks, making work safer. Another benefit to offsite construction is the ability to control wastage which would typically occur on a traditional site (Ajayi *et al.,* 2015).

Notwithstanding the many benefits of offsite construction, there are also barriers to its implementation. Generally, before a company can start to produce prefabricated component, a factory is required to be built. It is reported that that prefabrication has a high initial cost (Goodier and Gibb, 2007) and that to setup costs are also quite high (Blismas and Wakefield, 2009). There is also a general perception within the housebuilding industry that building homes using prefabrication is more expensive than the conventional methods of construction and therefore creates a barrier to its use. This can be seen in a survey undertaken by Pan *et al.,* (2008), involving 100 house builders, where they believed higher capital costs to be a significant barrier to prefabrications use. Notwithstanding the initial cost, it is widely believed to have a whole reduced life costing (Goodier and Gibb, 2007).

A study by Blismas and Wakefield (2009) identified a general lack of guidance and information on prefabrication as a significant barrier to its implementation. This lack of knowledge can also be seen in a study on the UK's house builder's utilisation of prefabrication. The study found a lack of previous experience as a very significant factor in not using prefabrication (Pan *et al.,* 2008). This further backs up what Blismas and Wakefield (2009) identified, suggesting that even if a company may want to get involved in using prefabrication, the limit on the amount of information is proving to be a significant barrier.

The current method to build homes has been in place since the first homes were built; so many builders are reluctant to change this method, and the builders are attached to conventional building methods and their current roles and tasks. This is mainly as the industry is known to be resistant to changes (Hairstans, 2014). However, the blame for this barrier cannot all be blamed on the people reluctant to change. The current business model is also set up for a more traditional house building technique. It is suggested that prefabrication will require different payment terms and cash flow arrangements (Blismas and Wakefield, 2009).

Much of the current literature on prefabrication pay attention to the negative stigma attached to prefabrication. This is the perception of prefabricated homes from potential clients and end users. The negative association may cause people to avoid using prefabrication and opt to go for a more traditional style of housing. A case study on the constraints and barriers to prefabrication highlighted this and stated that the negative connotation related to prefabricated construction comes from the association with unsafe and poor construction that was previously used (Schoenborn, 2012). This is most evident in a report on the barriers to offsite use in the UK, which suggests that out of a sample of contractors 48% found there was a negative image associated with prefabrication are a potential barrier to its use (Goodier and Gibb, 2007).

RESEARCH METHOD

Data Collection

To elicit experts' opinion, based on their personal experience of the concept, phenomenological research is a useful approach (Creswell, 2013). This allows researchers to bracket out their experience in a bid to get the first-hand experience from the participants. As such phenomenological approach was used in the study. Interviews were carried out with 12 information-rich participants to explore the strategies for maximising the benefits of offsite construction as well as the measures for mitigating its barriers. This approach allows the researchers to gain in-depth view of the concept by interacting with information-rich participants (Creswell, 2013). In line with Creswell (2013) position that purposive sampling allows researchers to select the most appropriate respondents, and Polkinghorne (1989) recommendations that between five and 25 respondents are suitable for a phenomenological study, 12 respondents were purposively selected for the study. Table 1 presents information about the participants, with their years of experience of prefabricated components and offsite construction ranging from 5 - 21 years.

Table 1: Overview of the research participants

Categories of respondents	Number of participants	Interviews Nos	Average years of experience
Designers (Architect, Arch Technologist, Civil Eng.)	3	1, 12, 4	14
Construction/project managers	3	2, 3, 6	12
Components manufacturers	3	5, 8, 11	7
Foreman	1	9	21
Site supervisors	2	7, 10	16

The participants were informed of the identified benefits of offsite construction and were asked to reflect on how such benefits could be maximised to enhance its increased adoption in the industry. Also, they were asked to explain how the current hindrances to the broad adoption of the modern method of construction could be mitigated. The 12 interviews were carried out face-to-face within six months, and they were recorded with the participants' consent and transcribed for qualitative analysis.

Data Analysis and Findings

Content-driven thematic analysis was used to explore the implicit and explicit statements stemming from the transcribed data (Braun and Clarke, 2006). This approach allows a systematic process of data analysis that flow from narrow to broader unit of analysis (Creswell, 2013). The initially identified themes were further analysed to identify the broader categories of strategies for maximising the benefits of offsite construction and mitigating its impediments. Table 2 shows the identified themes, their sub-categories and the interviews from which they emanated.

DISCUSSION

This section discusses the findings of the study under the six main themes in Table 2.

Increased Digitalisation of the Construction Industry

Better use of technology was recognised as being an essential enabler of prefabrication, as it is capable of increasing build quality and minimise waste (Smith

2011). One respondent stated that "the industry must start innovating and first movers will see immense benefits and possibilities for gaining a competitive edge." It was recognised that "implementation at the design stage using BIM is where to start". This aligns with Smith (2011) who suggests that the future of prefabrication relies on BIM, which allows prefabrication to be flexible, through virtual simulation. As one respondent suggests, "it allows the company to identify parts of the building that can be done in a factory", giving confidence to the designers and contractors and allow them to push the limits. Nonetheless, using technological advancements to maximise the benefits of prefabrication does not stop with BIM. Changes in technology can be introduced at a production level. An example suggested by one respondent was that "technological advancements allowed wax models to be 3D printed and used and recycled in the casting of concrete". As such, further incorporation of new technology at both a design level and production level can go a long way in maximising the benefits of prefabrication. Further advances in industrial machinery and digitalisation will allow the processes to be even more precise and deliver an even product.

Government Facilitation of the Modern Method of Construction

Introduction of enabling legislations is a crucial measure for facilitating prefabrication. An interviewee suggests that "an increase in not only UK government strategies but EU policies as well could further reduce the time needed on site." This is especially as the respondents believe that "building regulations are not really suited to the use of prefabrication and often several visits are needed by planning inspectors". This means that government intervention at a regulatory level could help to maximise the benefits of prefabrication, especially as the government's own review suggests that the current policies are not supportive (Parliament, 2003). Such intervention will not only include the introduction of enabling legislation, but it will also require the government to demonstrate the method in their affordable housing scheme. The use of the government's purchasing power to facilitate a compulsory proportion of offsite components, similar to BIM level 2 mandate, will significantly drive the use of offsite construction. Where possible, the risk put on a company should be minimised. As one interviewee suggested, their company's receival of a grant to deliver homes was an excellent motivation for offsite construction. This suggests that an increase in grants could help reduce the risk for the companies and in turn encourage more companies to build factories to produce prefabricated homes.

Standardisation for Offsite Construction

The respondents believed that the slow progress in the use of offsite technology is partly due to the insufficient information available on the increasingly important method of construction. This is mainly as there is currently no industry-wide standardization of the components and element, in addition to the lack of sufficient performance standards for offsite construction. As one interviewee put it, "instead of focussing on standard house type, the industry should aim at mass customisation of building elements and components". "This will help the designers to drive offsite construction by designing for it". In line with this, Bertelsen (2005) adds that unlike traditional building components, there is no catalogue for existing prefabricated components to use in designs. This suggests that a designer willing to incorporate prefabrication may find it hard because the information is not easily available there. It is suggested that "standardisation of housing specification requirements" by key housing providers, such as housing associations and local authority, will go a long way in facilitating components standardisation.

Table 2: Identified strategies for enhancing the use of offsite construction

Theme identified from interviews and their sub-categories	Interviews
Theme A: Increased digitalisation of the construction industry	
A1: Increase the use of technology to enhance precision in factory	2, 3, 4, 5, 8, 11, 12
A2: Use of innovative products to aid factory works	1, 5, 8, 11
A3: Innovative technology to enhance factory waste reuse	3, 5, 8, 9, 10
A4: Increased use of technology for easier planning/sequencing	2, 3, 4, 5, 6, 8, 11
Theme B: Government facilitation	1, 2, 3, 4, 5, 7, 8, 9, 11
B1: Introduction of government policy to accommodate prefab	1, 2, 3, 5, 6, 7, 8, 10, 11, 12
B2: Affordable housing development through offsite technique	3, 5, 6, 7, 8, 10, 11, 12
B3: Govt. approval through grant funding for offsite delivery	1, 2, 4, 5, 7, 8, 9, 10, 12
B4: Use of government purchasing power in similar way to BIM	1, 4, 6, 7, 8, 9, 10, 12
Theme C: Standardization for offsite construction	2, 6, 7, 9, 11
C1: Mass customisation of components/elements, not house types	2, 5, 8, 9, 11
C2: Development of offsite construction performance standards	4, 6, 7, 8, 10,
C3: Housing associations to standardise their spec requirements	1, 2, 4, 6, 7, 8, 11, 12
Theme D: Education and Training	3, 8, 9, 10
D1: Professional bodies to provide upskilling training to their members	2, 6, 7, 12
D2: Incorporation of offsite delivery into the academic curriculum	6, 8, 10, 12
D3: Factory workers to be further trained to make quality products	1, 4, 5, 8, 10, 11
D4: New apprenticeship scheme on offsite construction	8, 11
D5: Training of onsite workers to enhance quality of build for prefabs	1, 3, 5, 8, 9, 11, 12
D6: Awareness and education on the available products &specifications	6, 10, 12
Theme E: Client Education and Awareness	
E1: Showhomes as proof of concepts (quality samples) to clients	
E2: Clients' education on the long-term benefits of prefabricated homes	
E3: Construction firms as both client and contractors to showcase it	
Theme F: Development of a new supply chain model	
F1: Companies to adopt vertical integration strategies	3, 4, 5, 11, 12
F2: Change in supply chain management to suit prefabrication	2, 6, 7, 8, 9, 11
F3: Long term project planning to incorporate factory works	2, 3, 6, 9, 11
F4: Integrated project team between client, manufacturer &contractors	1, 2, 3, 6, 9, 10
F5: Government support to drive supply chain development	1, 2, 3, 4, 5, 6, 7, 9, 10
F6: Preliminary consultation with components/elements suppliers	1, 2, 3, 4, 5, 6, 7, 8, 9, 11

Note: Themes A, B, C and D were identified as benefit maximisation strategies, while C, D, E and F are identified as impediments mitigating strategies.

Education and Training of Professionals

Many similar themes emerged around the needs for increased education of AEC professionals on the offsite construction technique. This is as a result of an inherent lack of knowledge around prefabricated homes and what can be achieved through its implementation. As such, it was suggested that "training schemes could be increased to further maximise the benefits of prefabrication". In a study by Pan *et al.,* (2008), involving housebuilding companies, the skill upgrading by training was identified as a driver to increase prefabrication. It is clear that precise and thorough training could go a long way in increasing the use of prefabrication. The interviewees suggested that "striving to train people by working on apprenticeships schemes for the next worker" would be a great way to drive prefabrication. Other potential ways of facilitating the training are through short professional development courses by professional bodies

and incorporation of "offsite construction technology into the academic curriculum". An interviewee opined that "architects must start to learn how to use small details to make prefabrication more appealing".

The method to minimise the lack of knowledge around construction could start at the university level and continuously topped up with seminars and events which could be supported by the appropriate professional bodies. Materials, elements and components manufacturers also have roles to play in making people aware of their products and the available specification. Through these different levels of technical and non-technical training, depending on roles, the professionals will be more aware of the offsite construction techniques with the likelihood of driving its implementation.

Clients' Education and Awareness

Clients as the key driver of construction projects are important stakeholders that could drive the use of offsite construction. However, the clients and the public also face a similar problem and shy away from using prefabrication as a result of low awareness of its potential benefits. A respondent suggested that "a way to minimise this barrier would be the introduction of clients and even other competitors into the factory to see how things are done and a look at the finished product". This suggests that if clients and other people in the industry know the benefits prefabrication cab offer, its adoption may be easier. Steinhardt *et al.,* (2013) agreed that managing the expectations of consumers through education and comparing the traditional and prefabricated houses will serve an important purpose. With an introduction of better ways to educate people in using prefabrication and its potential results, the barriers could be minimised, and more people could be encouraged to use the technology.

Development of a New Supply Chain Model

As the initial factory cost is the main barrier to offsite construction, the respondents believed that "vertical integration of manufacturing is essential to drive innovation and continuous improvement", especially as "some good companies use prefabrication in an industry that is highly fragmented". Vertical integration is an arrangement in which the supply chain is owned by the same company that produces the product. The supply side of the industry is not particularly suited to use prefabrication and a way to solve this could be a shift in thinking. The offsite market could behave like the car industry, benefitting from economies of scale by reducing intermediaries.

Steinhardt *et al.,* (2013) opined that an integrated supply chain would bring many benefits and could be achieved by negotiations between supplier and builders. If a long term and relationships can be formed between suppliers and contractors, the housing manufacturing process has the potential to become more straightforward and efficient. The increased involvement in supply-side changes could work in reducing the barriers for the use of prefabrication. A more collaborative working that is totally different from the "over the wall syndrome" and blames culture bedevilling the construction industry (Ajayi *et al.,* 2016) will be essential for harnessing the benefits of offsite construction. For instance, a "preliminary consultation with suppliers", as one respondent put it, will be requisite for effective design for offsite construction.

CONCLUSION

Notwithstanding the positive impacts of offsite construction on construction productivity and quality, its adoption has been slowed by some barriers. Using a phenomenological approach, this study investigates the strategies for harnessing the

benefits of the modern methods of construction as well as the measures for mitigating its impediments. The study suggests that the requisite for broader adoption of offsite construction include increased digitalisation, standardisation for offsite construction government support, education and training of construction professionals, increased awareness by the clients as well as the development of favourable supply chain model.

The study implies that offsite construction could not become well adopted in the industry without proper education for both the construction professionals, who are expected to have the technological know-how, as well as the clients that are the drivers of construction projects. This requires both formal and informal trainings as well as the promotion of its many benefits by the industry stakeholders. This is especially as its adoption is still hindered by negative images among the clients. The knowledge, awareness and practice of the modern method of construction could be further expedited through an improved standardisation of the building components and elements to facilitate easy specification, reproduction and market structure for the elements. As the current supply chain model within the industry impedes the growth of offsite construction, it is essential that a more integrated system of the supply chain is facilitated through enhanced collaboration and vertical integration. With the government being major clients and enablers of the industry, the government is not only expected to create enabling legislation and provide financial incentives but are also to deliver their projects through offsite technique.

Based on emerging themes from the study, the research in this area will benefit from further studies that focus explicitly on the supply chain for offsite construction as well as the roles of government as a crucial enabler of offsite construction.

REFERENCES

Ajayi, S O, Oyedele, L O, Akinade, O O, Bilal, M, Owolabi, H A, Alaka, H A and Kadiri, K O (2016) Reducing waste to landfill: A need for cultural change in the UK construction industry, *Journal of Building Engineering*, 5, 185-193.

Ajayi, S O, Oyedele, L O, Bilal, M, Akinade, O O, Alaka, H A, Owolabi, H A and Kadiri, K O (2015) Waste effectiveness of the construction industry: Understanding the impediments and requisites for improvements, *Resources, Conservation and Recycling*, 102, 101-112.

Arif, M, Killian, P, Goulding, J, Wood, G and Kaushik, A (2017) Barriers and challenges for offsite construction in UK housing sector, *In: Proceedings of the International Research Conference*, 11-12, University of Salford, Salford.

Bertelsen, S (2005) Modularisation: A third approach to making construction lean? *In*: *13th International Group for Lean Construction Conference*, International Group on Lean Construction, 81.

Blismas, N and Wakefield, R (2009) Drivers, constraints and the future of offsite manufacture in Australia, *Construction Innovation*, 9(**1**), 72-83.

Braun, V and Clarke, V (2006) Using thematic analysis in psychology, *Qualitative Research in Psychology*, 3(**2**), 77-101.

Creswell, J W (2013) *Qualitative Inquiry and Research Design: Choosing among Five Approaches 3rd Edition*, Thousand Oaks: Sage.

Friedman, A (1992) Prefabrication versus conventional construction in single-family wood-frame housing: Costs of conventional and prefabricated Canadian homes compared in a survey of 15 manufacturers in the provinces of Quebec and Ontario, *Building Research and Information*, 20(**4**), 226-228.

Goh, M and Goh, Y M (2019) Lean production theory-based simulation of modular construction processes, *Automation in Construction*, 101, 227-244.

Goodier, C and Gibb, A (2007) Future opportunities for offsite in the UK, *Construction Management and Economics*, 25(**6**), 585-595.

Hairstans, R (2014) *Building Offsite: An Introduction*. Edinburgh, Scotland: UKCES.

Harrison, H, Mullin, S, Reeves, B and Steven, A (2012) *Non-Traditional Houses*. UK: BRE.

Hong, J, Shen, G Q, Li, Z, Zhang, B and Zhang, W (2018) Barriers to promoting prefabricated construction in China: A cost-benefit analysis, *Journal of Cleaner Production*, 172, 649-660.

Johnsson, H and Meiling, J (2009) Defects in offsite construction: Timber module prefabrication, *Construction Management and Economics*, 27(**7**), 667-681.

Killian, P, Arif, M, Wood, G and Kaushik, A (2016) Offsite construction in the UK housing sector: Barriers and challenges, *In*: *Modular and Offsite Construction (MOC) Summit*, 1(**1**).

Pan, W, Gibb, A G and Dainty, A R (2008) Leading UK housebuilders' utilization of offsite construction methods, *Building Research and Information*, 36(**1**), 56-67.

Parliament (2003) *Modern Methods of House Building, Post Note December 2003, Number 209*. London: Parliamentary Office of Science and Technology.

Polkinghorne, D E (1989) Phenomenological research methods, *In:* S Hailing and R Valle (Eds.) *Existential-Phenomenological Perspectives in Psychology*. New York: Springer, 41-60.

Schoenborn, J (2012) *A Case Study Approach to Identifying the Constraints and Barriers to Design Innovation for Modular Construction*. PhD Thesis, Virginia Tech.

Siebert, M, Rodrigues, L, Gillott, M, Hines, E and Rich, D (2018) Identifying the barriers to change in the UK housebuilding industry future. *Cities and Environment*, 4(**1**).

Sinesilassie, E G, Tabish, S Z S and Jha, K N, 2017 Critical factors affecting schedule performance: A case of Ethiopian public construction projects-engineers' perspective, *Engineering, Construction and Architectural Management*, 24(**5**), 757-773.

Smith, R (2011) *Prefab Architecture: A Guide to Modular Design and Construction*. Hoboken, NJ: John Wiley and Sons.

Steinhardt, D A and Manley, K (2016) Adoption of prefabricated housing-the role of country context, *Sustainable Cities and Society*, 22, 126-135.

TOWARDS AN ONTOLOGY-BASED APPROACH TO MEASURING PRODUCTIVITY FOR OFFSITE MANUFACTURING METHOD

Kudirat Ayinla[1], Franco Cheung[2] and Abdel-Rahman Tawil[3]

[1&2] *School of Engineering and the Built Environment, Birmingham City University, Millennium Point, Birmingham, West Midlands, B4 7XG, UK*

[3] *School of Computing and Digital Technology, Birmingham City University, Millennium Point, Birmingham, West Midlands, B4 7XG, UK*

The steady decline of manual and skilled trades in the construction industry has increased the recognition of offsite manufacturing (OSM), an aspect of Design for Manufacture and Assembly (DFMA) methods as one way to boost productivity and performance. However, existing productivity estimation approaches are carried out in isolation thus limiting the sort of result obtained from such systems. Also, there is yet to be a holistic approach that enables productivity estimation using different metrics and integrates experts' knowledge to predict productivity and guide decision making at the early development stage of a project. This study aims to develop a method that can be used to generate multiple estimations for all these metrics simultaneously through linking their relationships. An ontology-based knowledge modelling approach for estimating productivity at the production stage for OSM projects is proposed. A case study of panel system offsite is used as a proof-of-concept for data collection and knowledge modelling in an ontology. Results from the study through the use of rules and semantic reasoning retrieved cost estimates and time schedule for a panel system production with considerations for different design choices. It is thus proven that systemising the production process knowledge of OSM methods enables practitioners to make informed choices on product design to best suit productivity requirements. The developed method helps to reduce the level of uncertainty by encouraging measurable evidence and allows for better decision-making on productivity.

Keywords: DFMA, estimating, offsite-manufacturing, ontology, productivity

INTRODUCTION

The improvement of productivity and performance has long been an area of interest in the construction sector. Labour productivity in construction is reported to be low compared to that of other sectors, e.g. manufacturing (Eastman and Sacks 2008), which has led to several questions including whether productivity is accurately measured in the first place. This is mostly linked to the long-standing inefficiency associated with conventional methods of construction. The impact of low productivity is significant as it affects economic growth and welfare of a country. For instance, the level of productivity has been linked directly to the affordability of housing (Tran and Tookey 2007). Traditionally, the performance measurement of construction works is

[1] kudirat.ayinla@mail.bcu.ac.uk

Ayinla, K, Cheung, F and Tawil, R-A (2019) Towards an Ontology-Based Approach to Measuring Productivity for Offsite Manufacturing Method *In:* Gorse, C and Neilson, C J (Eds) *Proceedings of the 35th Annual ARCOM Conference,* 2-4 September 2019, Leeds, UK, Association of Researchers in Construction Management, 587-596.

based on project time, cost and quality. More recently, other indicators such as client satisfaction and environmental requirements, etc. have been included (Bassioni *et al.,* 2004, Robinson *et al.,* 2005). The use of performance benchmarking through key performance indicators (KPIs) are very common in the industry (Robinson *et al.,* 2005, Yang *et al.,* 2010). These criteria are mostly qualitative and can be subjective. More importantly, there is arguably a lack of productivity measurement, including estimating and measuring the actual productivity with the use of KPIs. There are also views that the construction industry in many countries are not doing well in terms of measuring productivity (Tran and Tookey 2007, Kenley 2014) due to the craft-based nature of the industry.

Since the recent propagation of cross-industry learning from other sectors (e.g. manufacturing) to construction in the UK (Pan and Sidwell 2011), the industry has started to implement production processes similar to that of manufacturing. An example is through the implementation of Design for Manufacture and Assembly (DFMA) concepts such as offsite manufacturing (OSM). OSM presents a way to reduce the number of on-site personnel by moving some major aspects of the construction process to a controlled environment and is continuously getting recognised as a way to boost the productivity of the construction industry (Huang *et al.,* 2009). As construction operations are being moved to manufacturing in OSM, it gives the industry an opportunity to consider approaches being used in manufacturing such as the use of knowledge-based approaches through ontology knowledge modelling to estimate, measure and improve productivity. An ontology is used to formally represent knowledge in a particular domain and supports rules and reasoning in order to facilitate computer processing and knowledge sharing. The development of ontology can enable automated productivity estimation, which can be essential to facilitate continuous improvement as it can provide real-time estimates as feedback for design development.

In this study, a review of existing productivity measurement methods and frameworks commonly used in the construction sector is carried out in order to acquire an understanding of their applications, limitations, and to identify opportunities for improvement. The potential for the use of ontology in modelling the knowledge of the product development stage of OSM projects for estimating productivity is revealed using the case of a panel system manufactured off-site. A framework to represent the ontology for cost and time productivity estimation is proposed and implemented using the ontology editor (Protégé) to facilitate reasoning and computation. This is supported with semantic rules to enable estimation of the production cost and time for offsite manufacturing method.

Productivity in a Construction Context

Performance and productivity are sometimes used interchangeably by practitioners. However, these words are different and are measured using a set of different criteria. Performance measurement is said to involve a process of establishing a set of parameters/criteria of desired results at which actual results are measured against (Yang *et al.,* 2010). Productivity, on the other hand, is defined as the level of efficiency in terms of using resources in the production of goods and services (Tran and Tookey 2007). Productivity is calculated as a measure of an output of a process to the corresponding input over a given period of time (Cox *et al.,* 2003). Performance measurement includes a more comprehensive analysis of some indicators which can be both financial (e.g. turnovers, cash flow, profit and share price) and non-

financial (e.g., client satisfaction, client changes, motivation, business performance and health and safety) (Cox *et al.,* 2003). Hence, productivity is an aspect of performance or can be described as a measure of 'process performance'.

According to previous researches (Kenley 2014, Yi and Chan 2014), the productivity in the construction industry has different meanings across the disciplines. Although it is mostly measured as the ratio of input and output, the expected type of input and output differs based on disciplines. A common approach in measuring construction productivity is to observe from different levels. Kenley (2014) categorised it using three levels: (i) onsite productivity -measured according to labour output, activity scheduling and resource management (as the classification may not have taken into account off-site activities, a more appropriate expression would be project level productivity) (ii) firm productivity - measured best practices, innovativeness and management ability across projects, (iii) industry productivity measured according to research, training, standards, investments and skills. At each level, productivity has different methods of measurement. This study looks at a more finite level than project level, i.e. offsite production level. The measurement at the offsite production level is described in the next section.

Measuring Construction Productivity with Respect to Time, Cost and Quality

A commonly used technique for measuring productivity at an offsite production level is the evaluation of the 'man hour per unit'. This approach is used to measure labour productivity by determining the ratio of the input to output (i.e. input/output). Usually, a lower value indicates better result (Park *et al.,* 2005, Malisiovas 2010). The measurement metric for this method is the labour time taken to produce an output. Although simple and direct, the limitation of this method is its inability to measure accurately when the unit output encompasses more work efforts that are not easily quantifiable (Cox *et al.,* 2003). This could be partly because the relationships between variables cannot be determined with this method. Other time-based models include experienced-based models and work sampling method. Experience-based method is one of the oldest methods that have existed before the development of technology-based approaches, where productivity is mainly measured based on expert's experience and compared to previous similar projects (Malisiovas 2010). The reliability of this method is not guaranteed due to the uniqueness of construction projects and the subjectivity of personal judgement. Work sampling method uses a statistical sampling theory to measure the time involved to complete various activities. It identifies productive work hours from the overall work hours by collecting data through methods such as video recording, observation tour, time-lapse photography and many more (Thomas *et al.,* 1990). The limitation of these time-based models for control is that they ultimately focus on measuring the time taken to produce an output alone, which can be at the expense of controlling other factors such as cost and quality. Reducing the time taken does not equate to obtaining the best quality and optimum cost.

There exist also some cost-based models that utilise cost as a measure of productivity. A common and simple approach is the evaluation of 'cost/unit' i.e. the pounds' value associated with producing one unit of work. This is an aggregation of cost variables such as the material, labour, plant, and waste. Similar to the 'man-hour per unit' method, this approach also fails to give an accurate measure for a more complicated unit of output. Another method using cost metric is the cost reporting method used to monitor productivity rate by benchmarking and comparing cost against past projects.

This is mostly used internally by organisations and requires historical data from past projects (Malisiovas 2010). Data collection can be very time consuming and prone to error. Also, possible causes of low productivity cannot be determined hence, limited opportunity for improvement. Lastly, productivity can be measured using the quality of work as the metric of measurement. The 'quality control/rework' method measures productivity by calculating the change in time and cost (i.e. man-hours and aggregated cost) for an output due to a repair work (Cox *et al.,* 2003). Reducing the amount of rework on a job reduces the unit cost and thus profit for a specific task is increased.

The discussed methods all present a good means of measuring the productivity of a process. However, they are limited to the use of just one metric at a time for measuring productivity as typically, cost, time, or quality productivity matrices are estimated and measured independently. Also, there is a challenge in collecting relevant information for estimation and comparison. For instance, an increase in output may not lead to an improvement in quality. Likewise, reduced time may reduce the cost associated with labour, it does not change other cost variables such as materials, plant, waste, and rework. Therefore, there is a need to develop an approach that can be used to generate multiple measurements for all the metrics simultaneously through linking their relationships. The multiple productivity measurements will give a greater opportunity to improve design decisions.

Ontology-Based Productivity Measurement for DMFA Project

Ontology is the act of 'formally' representing 'explicit' knowledge based on a shared 'conceptualization' (Gruber 1995). It is used to formalise the shared world view (idea or knowledge) of a community so as to aid understanding and communication. Ontologies are capable of modelling knowledge in a domain as well as their interrelationship and features as an advancement of locally-based knowledge repositories as it enables the use of artificial intelligence to facilitate automated expert advice (Cutting-Decelle *et al.,* 2007). The development of rules in an ontology facilitates reasoning which is used to generate results that mimic an expert's decision. Given these functions, ontology can be applied in facilitating multiple productivity measurements. This is particularly important in terms of generating multiple units of productivity measurements simultaneously in a factory production line setting.

OSM involves different variables and input that can be measured in terms of productivity. Compared to conventional construction methods which are labour intensive and workforces are the dominant productive resources (Yi and Chan 2014), OSM involves moving construction operation to a closed environment and the use of methods similar to manufacturing. Hence, reduced human labour is needed to complete a task in OSM. The productive resources for a manufacturing method are both the tools (robotics, machines) and the workforces (onsite and offsite) as the construction method is not craft-based. Therefore, whereas labour input is the most measured factor for the conventional method, there is arguably a need to include other inputs in the case of manufacturing. For DFMA projects, these inputs will typically include product related features (such as the size, weight, structural stability), production and assembly factors (in terms of sequence, activities, and resources). Therefore, systemising knowledge of the different stages of OSM through creating an accurate representation of the relationships between productivity metrics with an ontology can facilitate automatic generation of multiple measurements of productivity.

The ontology development in this study aims to represent the underlying principles and concepts of OSM as well as their interrelationships to enable productivity

measurement. Experts' knowledge is also modelled in the knowledge-base so as to facilitate reasoning and improve the output from the computation.

METHODOLOGY

In order to fulfil the aim of the research (to understand the production process of OSM so as to estimate the productivity of the process) a case study approach is selected. This method is considered the best match in fulfilling the aim of the research because a holistic in-depth exploration and understanding of OSM production process is required (Yin 2009). This sort of data (primary data) required for developing the ontology is not readily available in literature and most likely gathered through an in-depth study of the phenomenon (OSM) in its real-life context. A single-case design is adopted as the study seeks to develop a proof-of-concept and one case is deemed acceptable to prove or disprove the idea (Yin 2009). The choice of case study is guided by (i) availability of data on different types of product and processes (ii) use of advanced methods production process (robots) that allows time metric to be measured automatically. The selected case fulfils these criteria.

The use case features a light steel frame (LSF) panelised offsite production process on a manufacturing line in the factory for a 2-storey semi-detached house. Multiple sources of data are used to develop the ontology for real-time productivity estimation. Data collection was done in two phases, first is through document review (technical documents including as-built drawings, process flow documents, cost and time schedule documents, and quality reports). The data from this stage is used to populate the product and process ontology (i.e. concepts generation and classifications) and compilation of information about the production and assembly sequences, resource allocations, and cost and time schedules. The second phase of data collection was done through focus groups and discussions with professionals (the design and production team). The purpose is to capture expert knowledge regarding design decisions that influences productivity and also to verify the ontology developed. The last stage verification also features a validation process where expert result is compared to the result from the ontology.

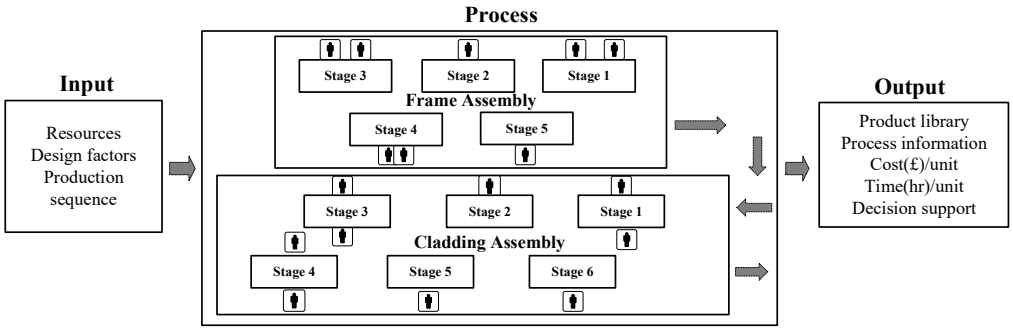


Figure 1: LSF panel system semi-automated linear production process

The production method modelled in this case is a 'semi-automated linear production process' where stages are sequential and some of the processes are automated (Figure 1). The breakdown of the production sequence on the line is identified and the corresponding task at each stage modelled. The 2-storey semi-detached house is separated into panels - wall panels, floors panels, etc. Each of these is further broken down into a number of smaller unit panels (up to 32 external units) as output from the production line. The factory production process consists of two major stages - frame assembly (building skeleton) and cladding assembly (building enclosure). The materials, upon reaching the factory move through these stages (which are further

broken down into tasks) until each unit is completed (Figure 1). The ontology thus models the knowledge of the input and the process to measure the output. Rules and queries included in the ontology are those that enable the answers on productivity and design factor implication to be retrieved.

The ontology development process follows Meth-ontology approach, one of the ontology development methods widely encouraged by researchers because it thoroughly analyses the lifecycle of an ontology (Fernandez *et al.,* 1997, Corcho *et al.,* 2003). The Meth-ontology guideline steps followed are: (i) the specification of objectives (ii) gathering information from a case study (iii) the conceptualisation - development of a semi-formal representation of the knowledge (iv) the formalisation - representing the knowledge formally using an ontology builder/editor (Protégé) (v) the implementation - representing the ontology in a machine-readable language (Web Ontology Language - OWL) (vi) the evaluation of results. Due to the interest in cost and time estimation, the high-level classification and properties used to describe the products is according to the UK standards based on the New Rules of Measurement 2 (RICS 2012). For lower level classification, there is not enough granularity in NRM2 to classify the complex offsite concepts. Thus, a bottom-up approach according to how experts are classifying components and aggregating cost per unit is adopted based on the case study to develop the ontology.

ANALYSIS AND RESULTS

The analysis and results follow the Meth-ontology approach explained in the previous section. The first two stages have been covered in the methodology section.

(i) Conceptualisation - this stage features the development of a semi-formal representation of the knowledge gathered. Figure 2 shows the architecture of the system which is designed such that information on specific intended questions (i.e. related to cost/unit or time/unit) can be retrieved. Their relationships follow as: panelised production system (PanelSystemProduction) is composed of some production stages (ProductionStages) and has outputs in the form of panels (Products). The products are composed of some materials (Material), and the production stages are composed of some activities (JobTask) which requires operatives (Labour) and tools (Tools) to be executed.

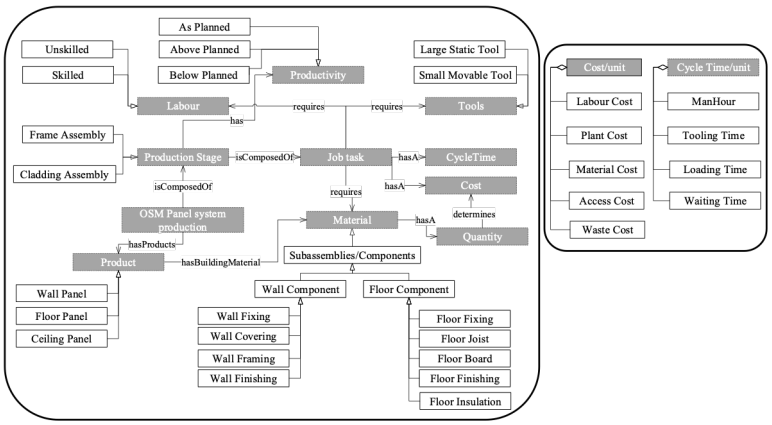


Figure 2: Structure of the OSM Panel System Productivity

(ii) Formalisation - the knowledge from the conceptual design is further developed formally in an ontology builder/editor (Protégé). Each class is populated with subclasses and property assertions is used to build relationships between the instances of a class or to link an instance to a data value. Object properties are included to

describe the relationship between a product and its resources or production process (Figure 3). Data-type properties are included to allow the computation of values used to determine productivity such as length, width, height, area, quantity, counts, etc. The productivity in terms of cost/unit is determined through aggregation of labour, material, plant, transportation and waste costs. Similarly, the time/unit is determined through an aggregation of the man-hour (work done by operatives), tooling time (for robot operations), loading time (putting the panels in position) and waiting time (from one station to another). To allow the ontology to compute the cost/unit and time/unit for each panel, Semantic Web Rule Language (SWRL) rules are included to facilitate reasoning and enable inferences about an instance.

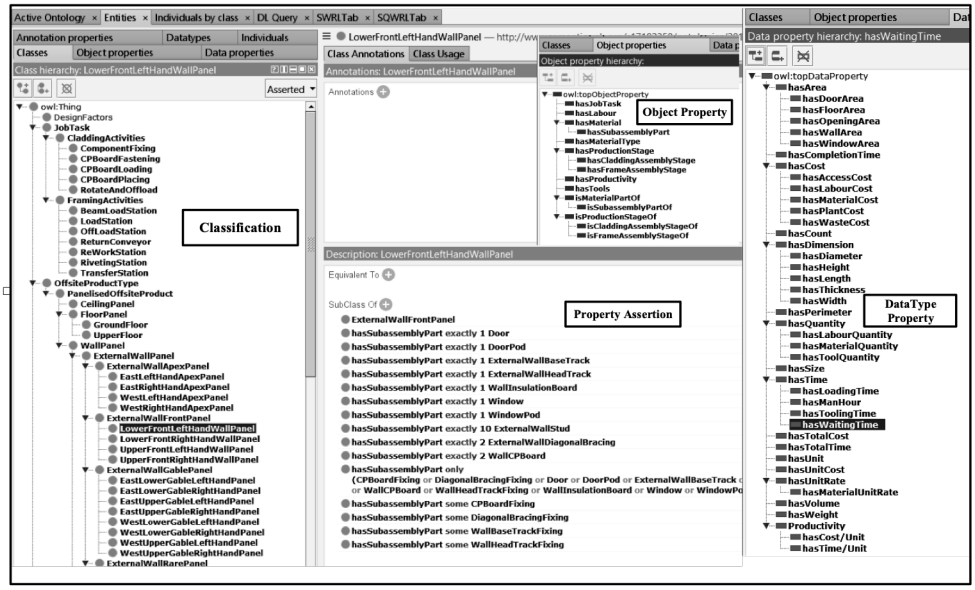


Figure 3: Modelled concepts in the ontology with Protégé

(iii) Implementation - the ontology is represented in a machine-readable language (Web Ontology Language - OWL) to enables rich set of modelling constructors. Rules are built into so as to query the ontology to retrieve information such duration of activities/task, type and number of operatives for a task, materials for a panel etc. In order to calculate cost, quantities must first be calculated. For wall panels, the quantity of cladding material for each wall panel is first calculated and this is multiplied by the corresponding unit rate. The SWRL rule to calculate the quantity and then the cost are as follows:

WallCladdingComponents (? wc) ^ hasLength (?wc, ?l) ^ hasHeight(?wc, ?h) ^ swrlb:multiply(?ca, ?l, ?h) -> hasWallArea(?wc, ?ca)

WallCladdingComponents (? c) ^ hasWallArea (?c, ?a) ^ hasUnitCost(?c, ?u) ^ swrlb:multiply(?q, ?a, ?u) -> hasMaterialCost(?c, ?q)

For this rule, an instance of a wall cladding (e.g. Cement Board) with an already specified length and height (in the ontology) is invoked and the SWRL built-in function - swrlb:multiply is used to relate these data in order to compute the quantity of the material. This results from running the rule are then picked up by the reasoner and fed back into the ontology as inferred properties (see Figure 3). However, swrl built-ins are not able to create expressions for obtaining a sum of a set of instances (i.e. nx) due to the open world reasoning assumption. Therefore, the SQWRL's operators are used to query the ontology in order to retrieve information for this

purpose. A query is this used to select the duration (time) of the production stage of a panel as follows:

> WallPanel(?p) ^ hasProductionStage(?p, ?pr) ^ hasLoadingTime(?pr, ?lt) ^ hasWaitingTime(?pr, ?wt) ^ hasManHour(?pr, ?mh) ^ hasToolingTime(?pr, ?tt) ^ swrlb:add(?t, ?lt, ?tt, ?wt, ?mh) . sqwrl:makeBag(?b, ?t) . sqwrl:size(?n, ?b) -> sqwrl:select(?p, ?pr, ?n, ?lt, ?wt, ?tt, ?mh, ?t)

From the query result (Figure 4), the total time for all activities for the wall unit (panel 4) can be calculated by summing up the retuned values. This gives an estimate of cycletime/unit (t) for that product through an aggregation of the sum of the man-hour (mh), tooling time (tt), loading time (lt) and waiting time (wt).

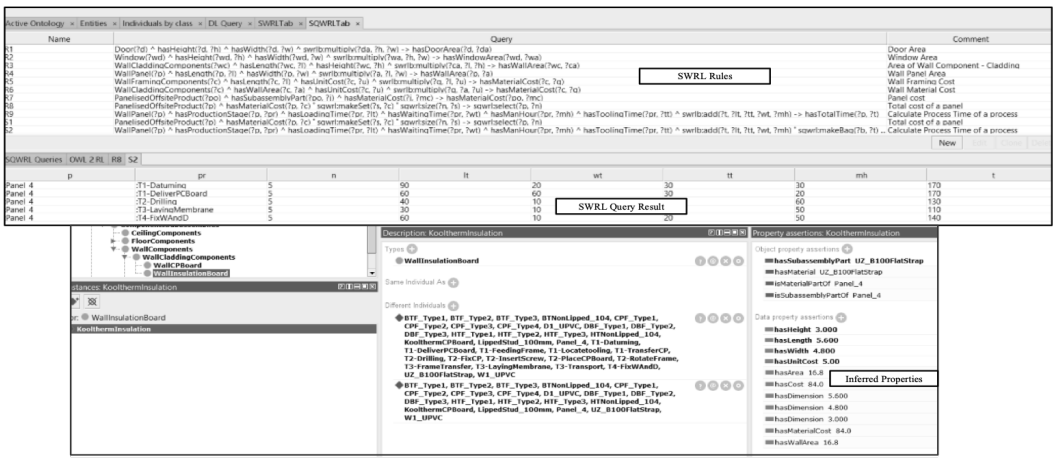


Figure 4: SWRL rules to enhance reasoning and computation in the ontology

Also, the results from Figure 4 includes some design decisions specified on the product and process. Evaluations of the implications of design changes on products (e.g. size, weight and geometry of the panels) and process changes (e.g. reduced/increase labour for a particular operation and/or the introduction of robots to automate some activities) are captured in the knowledge-based system. An example is implemented in the ontology through a rule to evaluate the implication of panel sizing on cost and time per unit. The rule is included in the ontology to classify an instance of a wall panel with an area greater than 30m2 as big and thus consequently increase the number of operatives (for handling) in all stations by one.

> WallPanel(?x) ^ hasWallArea(?x, ?a) ^ swrlb:greaterThan(?a, 30) -> LargePanel(?x)
>
> LargePanel(?lp) ^ hasOperativeCount(?p, ?c) ^ swrlb:add(?b, ?c, 1) -> hasLabour(?lp, ?b)

For this rule, an instance of a wall panel with an area greater than 30m2 is considered big and thus consequently, an increase of plus one on the number of operatives at all stations in order to give allowance for handling. This rule is to guide decisions and inform choices regarding considerations of alternatives where possible.

DISCUSSION

The results from the analysis show that there is a possibility of estimating both cost and time metrics of productivity simultaneously. The SWRL rules enabled inclusion of mathematical expressions and formula to calculate the cost of the products by determining the quantities of materials and subsequently the costs of labour, materials, and machining for each offsite panel. After running the rules and invoking the reasoner, the cost of materials, labour and plant for each component of a panel are generated (Figure 4). Similarly, the rules developed are used to estimate the

production time for each panel, the result from the reasoner generates the material loading time, tooling time, waiting time and man-hour (Figure 4). This presents a way to generate cost and time metrics and combine previous measurement approaches commonly used in the industry such as cost/unit (Cox *et al.,* 2003) and time/unit (Malisiovas 2010). Also, experts' knowledge on design implications and production sequence captured in the ontology influences the result from the reasoning process.

The challenge with the use of the knowledge-based system and the rule development is that it is limited to some simple mathematical expressions. For instance, generating the overall total cost/unit and time/unit for all 32 panels is challenging because of the limited capabilities of SWRL and summing up the results from individual panels needs to be done manually or using other systems (e.g. Excel). This implies that there is a need to achieve these other tasks using other means. Using an external user interface and system can come handy in performing these tasks. An Application Programme Interface (API) such as OWL-API can be used to link the knowledge-base with an external application to perform these operations. OWL-API can interact with the ontology to fetch data needed to generate estimates for cost/unit and time/unit.

Also, compared to the onsite construction method, one of the challenges encountered in formalising the knowledge is that offsite processes vary in products, process, and equipment used for manufacturing; e.g. timber offsite production varies significantly in products, processes, and techniques from that of steel or concrete. Similarly, compared to manufacturing, construction projects are often times unique and sometimes have non-repetitive operations thus limits the effort in measuring productivity of the process. The ontology will need to be expanded in its capacity so as to capture changing conditions that happen frequently in construction. Continuous changes or alterations in the OSM processes or operations are necessary to cope with the market requirements, and largely influenced by individual project requirement.

CONCLUSIONS

The study presents an ontology-based approach to estimating cost and time metrics for measuring the productivity of the manufacturing process of offsite method using a panel system OSM as a proof-of-concept. It is proven that an ontology-based estimation is effective in allowing more than one metric of productivity measurement to be obtained such as cost and time. The study concludes that the development of an ontology to capture the knowledge of the OSM products and processes although will not directly improve productivity, can help with decision support on product and process design at the PD stage which can influence productivity significantly. The use of an ontology to model alternatives choices at the PD stage will be able to give a clearer picture of output for every change in input through the estimation of the process performance indicators. Given that the use of rules (i.e. SWRL) is limited to some mathematical expressions, further work on communicating with the ontology through an Application Programme Interface (API) such as OWL-API and linking with other systems will need to be explored to perform these operations.

REFERENCES

Bassioni, H A, Price, A D F and Hassan, T M (2004) Performance measurement in construction, *Journal of Management in Engineering*, 20(**2**), 42-50.

Corcho, O, Fernandez-Lopez, M and Gomez-Perez, A (2003) Methodologies, tools and languages for building ontologies Where is their meeting point? *Data and Knowledge Engineering*, 46, 41-64.

Cox, R F, Issa, R R A, Asce, M and Ahrens, D (2003) Management's perception of key performance indicators for construction, *Journal of Construction Engineering and Management*, 129(**2**), 142-151.

Eastman, C M and Sacks, R (2008) Relative productivity in the AEC industries in the United States for on-site and off-site activities, *Journal of Construction Engineering and Management*, 134(**7**), 517-526.

Fernandez, M, Gomez-Perez, A and Juristo, N (1997) *Methontology: from Ontological Art Towards Ontological Engineering*, Mafiadoc, Available from https://mafiadoc.com/methontology-from-ontological-art-towards-ontological-engineering_59c6af251723ddb271e0e7ed.html [Accessed 28/07/2019].

Gruber, T R (1995) Toward principles for the design of ontologies used in knowledge sharing, *International Journal of Human Computer Studies*, 43, 907-928.

Huang, A L, Chapman, R.E and Butry, D T (2009) *Metrics and Tools for Measuring Construction Productivity: Technical and Empirical Considerations*, National Institute of Standards and Technology Special Publication 1101.

Kenley, R (2014) Productivity improvement in the construction process, *Construction Management and Economics*, 32(**6**), 489-494.

Malisiovas, A (2010) Construction Productivity: From Measurement to Improvement *In: Fifth Scientific Conference on Project Management (PM-05) - Advancing Project Management for the 21st Century Concepts, Tools and Techniques for Managing Successful Projects*, Heraklion, Greece.

Pan, W and Sidwell, R (2011) Demystifying the cost barriers to offsite construction in the UK, *Construction Management and Economics*, 29, 1081-1099.

Park, H, Thomas, S R and Tucker, R L (2005) Benchmarking of construction productivity, *Journal of Civil Engineering and Management*, 131(July), 772-778.

RICS (2012) *NRM 2: Detailed Measurement for Building Works 1st Edition*. Coventry: Royal Institution of Chartered Surveyors (RICS).

Robinson, H S, Anumba, C J, Carrillo, P M and Al-Ghassani, A M (2005) Business performance measurement practices in construction engineering organisations, *Measuring Business Excellence*, 9(**1**), 13-22.

Thomas, B H R, Maloney, W F, Horner, M W, Smith, G R, Handa, V K and Sanders, S R (1990) Modeling construction labor productivity, *Journal of Construction Engineering and Management*, 116(**4**), 705-726.

Tran, V and Tookey, J (2007) Labour Productivity in the New Zealand construction industry: A thorough investigation, *Australasian Journal of Construction Economics and Building*, 11(**1**), 41-60.

Yang, H, Yeung, J F Y, Chan, A.P.C, Chiang, Y H and Chan, D W M (2010) A critical review of performance measurement in construction, *Journal of Facilities Management*, 8(**4**), 269-284.

Yi, W and Chan, A P C (2014) Critical review of labor productivity research in construction journals, *Journal of Management in Engineering*, 30(**2**), 214-225.

Yin, R K (2009) *Case Study Research: Design and Methods Fourth Edition*. London: SAGE Publications.

INNOVATION AND LEARNING

EXAMINING CONSTRUCTION CONTRACTORS' INNOVATION THROUGH THE LENS OF EXPLORATION AND EXPLOITATION

Nipuni Sumanarathna[1] and Steve Rowlinson

Department of Real Estate and Construction, The University of Hong Kong, Pok Fu Lam Road, Hong Kong

This study investigates innovation deployment in construction contractor organisations through the lens of exploration and exploitation-learning approaches. Radical vs incremental classification of innovation has been linked with explorative and exploitative learning. Exploration is explained by radical innovation, which is the implementation of innovation in the organisational context. In contrast, exploitation is explained by i) incremental innovation, which is the utilisation of innovation and ii) continuous development of organisational activities. The learning theory demonstrates that organisations need to maintain a balance (ambidexterity) between these two learning approaches for their short-term and long-term survival. Following this argument, a research framework is presented to illustrate how contractor organisations exercise exploration and exploitation (as well as innovation) at project, project portfolio and organisational levels. The framework is based on the theoretical and empirical findings of prior studies which were published on highly ranked journals and conferences. A preliminary interview series with industry experts was carried out to validate the framework and shortlist potential contractor organisations as the case studies. Findings from the preliminary assessment reveal that contractors are way forward in implementing innovation and willing to share their knowledge on various newer innovation approaches. However, the client-driven nature of construction industry delays innovation of contractors, specially at project level. This is an ongoing research. As the future research direction, multiple case studies are yet to be done with the purpose of attaining holistic insights on recent innovative approaches of large-scale contractors in the Hong Kong construction industry.

Keywords: contractor organisations, exploration, exploitation, innovation

INTRODUCTION

Research in construction innovation has a history of more than thirty years, prompting debates over innovativeness in the construction industry, i.e. (Tatum, 1986). The industry has been mostly recognised for its lack of innovativeness (Blayse and Manley, 2004). The project-based nature of the industry has been highlighted as a limiting factor in terms of innovation, as project discontinuance and one-off outputs are widespread in the industry (Dubois and Gadde, 2002). In contrast, the change of current measures of innovation to a contemporary apprising method is emphasised (Bygballe and Ingemansson, 2014). Hence, this paper attempts to investigate innovation in the construction industry, adopting a contemporary perspective while

[1] nipuni@hku.hk

Sumanarathna, N and Rowlinson, R (2019) Examining Construction Contractors' Innovation Through the Lens of Exploration and Exploitation *In:* Gorse, C and Neilson, C J (Eds) *Proceedings of the 35th Annual ARCOM Conference,* 2-4 September 2019, Leeds, UK, Association of Researchers in Construction Management, 598-607.

considering its project-based and discontinuous nature, focusing specifically on construction contractor organisations.

Innovation generally connotes the implementation and development of breakthrough ideas (Van de Ven, 1986). Researchers tend to classify innovation based on the nature of output, impact of output and nature of process. In this study, innovation is defined considering the nature of output in the organisational context - as the implementation of a new product, process, system, strategy, policy or service in an organisation (Damanpour and Evan, 1984; Slaughter, 1998). Therefore, traditional measurements such as profit, number of patents, and R&D allocation might not be able to capture the innovation in organisational procedures, contracts arrangements and system integration methods (Bygballe and Ingemansson, 2014; Winch, 2003). Organisations should be able to assess the intangible benefits caused by innovation such as knowledge update, enhanced reputation and increased social networks (Slaughter, 1998).

More recently, the explore-exploit dichotomy has been adopted to explain innovation in organisational management research. This concept was initially introduced considering the nature of the process (March 1991). Exploration includes activities such as "search, variation, risk-taking, experimentation, play, flexibility, discovery, and innovation" (March 1991, p.71); and exploitation includes activities such as "refinement, choice, production, efficiency, selection, implementation and execution" (March 1991, p. 71). In a broader view, exploration suggests a search for new opportunities. On the contrary, exploitation involves improving the existing certainties. More recent studies tend to explain exploration and exploitation considering their nature of outcomes (Eriksson *et al.,* 2017). For instance, 'radical innovation' has been used to explain exploration, whereas 'incremental innovation' and 'continuous development' are adopted to explain exploitation (Eriksson and Szentes, 2014). The outcomes of exploration are less certain compared to exploitation, as exploitation utilises the existing knowledge and learns from feedback. Therefore, its consequences are quicker, more certain and more accurate.

The application of exploration-exploitation paradox into project-based settings has rarely been discussed in construction management research, particularly in the contractor perspective. Even though innovation in construction is mostly client-driven, contractors' involvement is inevitable (Slaughter, 1993). Early involvement of contractors caused by collaborative and digitalised procurement approaches has enhanced contractors' capabilities of fostering innovation in the industry (Bresnen *et al.,* 2003; Eriksson, 2013). Having selected qualitative research approach and large-scale contractors as the potential cases, this study attempts at answering the research question: how is innovation deployed in construction contractor organisations?

Theory: Exploration, Exploitation and Organisational Ambidexterity

Initially, the mutual exclusiveness of exploration and exploitation (also called explorative learning and exploitative learning) was accepted as a practical issue (March 1991). Subsequently, a contradictory view emerged highlighting organisations' ability to exercise and manage both exploration and exploitation simultaneously. The concept of ambidexterity was then introduced as the ability to balance exploration and exploitation. Three forms of ambidexterity have been identified in the previous literature, which are structural, temporal/sequential and contextual (Eriksson, 2013; Turner *et al.,* 2014). Structural ambidexterity is managing exploration and exploitation by allocating different organisational units. On the

contrary, undertaking these two learning approaches in different time periods is called temporal or sequential ambidexterity (Benner and Tushman, 2003; Tushman and O'Reilly, 1996). Contextual ambidexterity is integrating exploration and exploitation at individual, team, department or project level in an organisation. In organisations where contextual ambidexterity is adopted, trusting skills and capacities of employees to perform both exploration and exploitation is prioritised (Andriopoulos and Lewis, 2009). This form of ambidexterity is recommended for Project-based organisations (PBO), particularly to manage exploration and exploitation at project level (Gibson and Birkinshaw, 2004).

Construction Industry Context

As a project-based industry which forms temporary project settings to deliver one-off outputs, the whole process and result is uncertain and riskier. This heterogeneous nature discourages construction organisations' interest to adopt contemporary and innovative methods; in other words, exploration is hindered. However, recent arguments claim innovation in construction is often underestimated, and there is a necessity of acknowledging hidden innovation in the industry. The concept of exploration and exploitation has been applied in recent construction management research as a different perspective to explain innovation in the organisational context (Bygballe and Ingemansson, 2014). Eriksson (2013) investigated how construction project-based organisations (PBOs) manage exploration and exploitation at different organisational levels. Findings of research such as the impact of co-creation practices on exploration and exploitation in construction projects (Eriksson *et al.,* 2017) and forms of ambidexterity in projects (Eriksson, 2013) demonstrate the antecedents of exploration and exploitation as well as risks involved with explore-exploit paradox in construction process. Large and complex projects have been recognised for their ability to handle both exploration and exploitation. When a problem occurs such as time or cost overrun, project actors have sufficient resources to solve such problems by adopting innovative solutions (exploration). In contrast, exploitation has been recommended for small-scale and simple projects which have limited resources. Existing knowledge can be used to solve problems and secure project success (Eriksson, 2013; Turner *et al.,* 2014). The necessity of collaborative procurement approaches as a strong integrating mechanism to mitigate risks involved with explore-exploit paradox has been emphasised as well (Bresnen *et al.,* 2003; Eriksson, 2013). Following these arguments and adopting Eriksson and Szentes' (2014) explanations for exploration and exploitation, the following research framework is presented (see figure 1).

THE RESEARCH FRAMEWORK

As shown in the following research framework (see figure 1), organisational and project levels are shown in a hypothetical contractor organisation. At both levels, exploration and exploitation are exercised in different forms of ambidexterity (i.e. contextual ambidexterity at project level and structural ambidexterity at organisational level). Following Bygballe and Ingemansson's (2014) analytical model, the knowledge transfer between two levels is shown by arrows, i.e. project-to-organisation, organisation-to-project and within projects. Knowledge (obtained from learning) transitions among different levels is important to enhance organisations' capability to innovate (Bygballe and Ingemansson, 2014; Eriksson, 2013; Liu and Chan, 2016). Knowledge can be declarative (facts) and procedural (skills and routines) (Argote, 2012; Gherardi, 1999). Even though this framework does not

indicate the project portfolio level and their knowledge transitions to prevent confusions, the contextual ambidexterity is still applicable for project portfolio level.

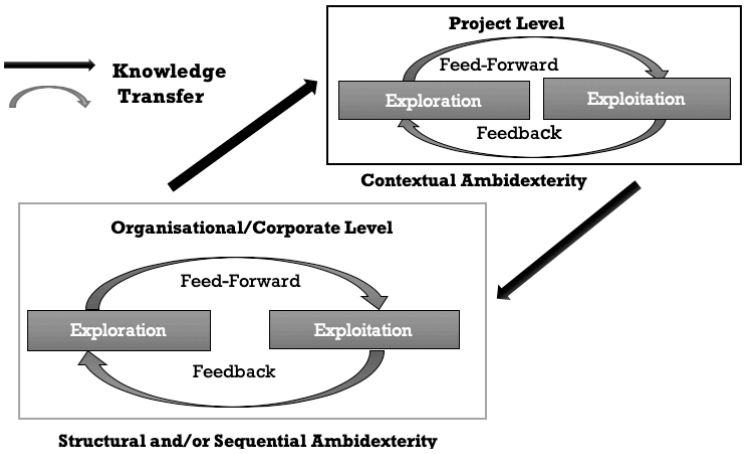


Figure 1: The research framework to explain innovation at different levels in construction contractor organisations

Constructs explanation

Having considered the nature of output of each learning approach, exploration of a hypothetical contractor organisation is explained by their radical innovation which is the implementation of innovation to address the emerging needs of the organisation (Eriksson *et al.,* 2017). Exploitation, on the other hand, is explained by the combination of incremental innovation and continuous development. Incremental innovation is defined as the utilisation of innovation, which is the known innovative solutions that have worked and are intended to use in future (without changes or with minor changes). Continuous development is explained as the fine-tuning of current work, which is not necessarily innovation (Eriksson and Szentes, 2014). As the framework suggests, both radical and incremental innovation can be observed simultaneously at project and project portfolio levels. Radical innovation at these levels can be spontaneous, and it can be considered as a problem-solving approach as well. In contrast, radical innovation at organisational level is well-planned and managed. The organisational strategies and policies for innovation can be clearly observed through radical and incremental innovation deployment at organisational level. Knowledge transfer through effective communication among different levels has also been addressed in this framework. For instance, the knowledge associated with exploration at project level turns into exploitation at organisational level.

The Hong Kong construction industry

This study is carried out in the context of Hong Kong construction industry. The industry is a leading construction industry in Southeast Asia as well as in the world and known for massive infrastructure and high-rise buildings (Rowlinson *et al.,* 2010). The industry's contribution to the economy, in particular the Gross Domestic Product (GDP), has increased from 4.0% in 2013 to 5.1% in 2017 (Census and Statistics Department The HKSAR, 2017) which makes the industry a crucial component in enhancing the economy and living standards in Hong Kong (Awale and Rowlinson, 2015; Chan *et al.,* 2013). Despite being an industry leader in the Southeast region, certain issues hinder Hong Kong's sustainable development. Health and safety awareness, labour shortage, ageing workforce, construction waste and landfill issues,

and the lack of collaborative nature of the industry are yet to be solved (Construction Industry Council, 2015; GovHK, 2015). The culture and structure of Hong Kong's construction industry comprise of both British and Chinese characteristics; hence, the industry itself is a mixture of the western and eastern world. Rigid and hierarchical administration in Hong Kong has been inherited by British sovereignty for Hundred and fifty-six years. This created a dearth of collaborative features in the whole construction process. Besides, the government (or clients) plays a major role in decision making (Rowlinson *et al.,* 2010).

Nevertheless, the industry is now undergoing one of its peak periods. Several strategies have been implemented to meet the demand and mitigate relevant industry issues such as recent interests in fostering innovation, collaborative procurement approaches, construction safety-the vision of 'zero accident' and digitalisation of process. The contribution of large-scale contractors in implementing these approaches is significant.

METHODOLOGICAL IMPLICATIONS

As the research methodology, the interpretivist stance and qualitative approach accompanying three research methods were considered to answer the research question. First, a preliminary interview series with industry practitioners who are experienced in implementing innovation in the Hong Kong construction industry was carried out. The objectives of this interview series are; i) validate the research framework and its theoretical arguments through studying the innovation deployment of contractor organisations, ii) examine the current status of Hong Kong construction industry regarding its innovation deployment and iii) shortlist the potential contractor organisations to conduct case studies. Through the literature review of this paper, the developed research framework with its theoretical arguments is discussed. The following section discusses the findings of preliminary interview series.

This is an ongoing research. Second and major research method, multiple case studies are yet to be done. Large-scale[2] contractor organisations in Hong Kong who are known for implementing innovation will be selected as the case studies. As the third and final research method, an expert interview series will be carried out to validate the research findings.

FINDINGS

Preliminary interview series

Five face-to-face semi-structured interviews were carried out in English with industry practitioners who represent contractor organisations, an engineering consultant organisation and a government construction organisation in the industry. All the interviewees were selected based on their experience, knowledge and contribution to the innovation in the Hong Kong construction industry as well as their managerial position in respective organisations. All the individuals have at least a degree or diploma in civil engineering, town planning or construction management with relevant professional qualifications, and two of them have obtained postgraduate qualifications as well. In addition to the five formal one-hour in-depth interviews, findings of two

[2] Contractors who are under the Category C for Buildings works, Port works, Road and Drainage, Site Formation and Waterworks. The categorisation is given by Development of Bureau for Public works in Hong Kong (Development Bureau The HKSAR, 2019).

informal interviews were incorporated to obtain the final output. The demographic information of participants is summarised in the following table 1.

Table 1: The demographic information of interviewees

Code	Position	Experience	Organisation
PI01	Director	15 years	Contractor Organisation
PI02	Head of Innovation	12 years	Contractor Organisation
PI03	General Manager-Innovation	07 years	Contractor Organisation
PI04	Manager	14 years	A government organisation for promoting innovation in the HK construction industry
PI05	Temporary Works Systems Manager	43 years	Private Engineering Consultant

All the interviews were audio-recorded, and transcripts were produced. The Thematic analysis technique was adopted incorporating NVIVO 12 software to identify three main themes (along with the objectives of preliminary interview series) which are i) innovation deployment of Hong Kong construction industry ii) case study selection and iii) innovation deployment of contractor organisations. The coding structure was then created adding sub-themes. The themes and sub-themes were selected based on the interview guideline as well. The following table 2 indicates a brief version of the coding structure.

Innovation in the Hong Kong construction industry (Theme 01)

All the interviewees have had a positive feeling regarding the innovativeness of Hong Kong construction industry and yet pointed out the necessity of having a digital transformation in the industry, an innovative procurement model for procuring projects which facilitates contractors' early involvement, collaboration and innovation. However, PIO5 was not satisfied with the current situation and justified his stance as "small scale innovation are just add-ons. They are not the revolution of the entire industry. It might enhance productivity or make it slightly more comfortable. However, it is not a revolutionary change or radical innovation". He further elaborated that the HK industry needs a client-driven digitalised system change, which is more efficient. PI03 pointed out that involvement of government can be observed through fund allocation, decision making, and establishing an organisation to promote innovation among construction stakeholders.

While agreeing to this statement, others stressed out the necessity of modifying current regulations to speed up the design approval process. Everyone mentioned that involvement of contractor organisations (large-scale main contractors) in fostering innovation is satisfactory. However, only a few numbers of contractor organisations are engaged or have a capacity to foster innovation due to the issues such as lack of resources and knowledge, lack of incentives, lower profit-margin, time-consuming design approval processes, lack of risk sharing procurement strategies and client-driven nature of the industry.

Selection of Case studies (Theme 02)

All the interviewees work or have worked in contractor organisations. Therefore, their judgement based on size, age, recent innovation practices, awards received, reputation and accessibility to obtain data were considered for shortlisting two potential case studies from nine large-scale contractor organisations who belong to Category C (see the footnote 1).

Table 2: The brief version of coding structure

Main Theme	Sub-theme(s)	
1.0 Innovation deployment of HK construction industry	1.1 Innovativeness-as an industry	
	1.1.1 Satisfactory, yet certain actions should be taken	
	1.1.1.1 Digital transformation	
	1.1.1.2 An innovative procurement model	
	1.1.1.3 Contractor's early involvement	
	1.1.2 Not satisfactory-revolutionary change is a must	
	1.2 Involvement of government	
	1.2.1 Satisfactory	
	1.2.1.1 having an organisation to promote innovation	
	1.2.1.2 fund allocation	
	1.2.1.3 decision making	
	1.2.2 Satisfactory, yet certain actions should be taken	
	1.2.2.1 modification of design approval process	
	1.3 Involvement of contractor organisations	
	1.2.1 Satisfactory	
	1.2.1.1 Yet, a few numbers of contractors are engaged	
	1.2.1.2 Incentives for contractors are not sufficient	
2.0 Case study selection	2.1 Name (i.e. Contractor A)	
	2.1.1 Size	
	2.1.2 Age	
	2.1.3 Recent innovation	
	2.1.4 Awards received	
	2.1.5 Other	
3.0 Innovation deployment of contractor organisations (validation of research framework)	3.1 Name (i.e. Contractor A)	
	3.1.1 Exploration-radical innovation	at organisational, project project portfolio levels
	3.1.2 Exploitation-incremental innovation	
	3.1.3 Exploitation-continuous development	
	3.1.4 Exploitation-continuous development	
	3.1.4.1 organisation-to-project	
	3.1.4.2 Project-to-organisation	
	3.1.4.3 Between projects (project portfolio)	
	3.1.4.4 within projects (project level)	

Innovation in Contractor Organisations (Theme 03)

Contractor organisations were examined in terms of their organisational structure, culture, innovation deployment strategies at organisational, project and project portfolio levels. A separate central division or a team has been established to manage innovation within organisations. However, project leaders are responsible for the innovation of each project. Innovation team acts as the facilitator and progress reviewer. In this regard, integration and collaboration among different business units and different organisational levels (corporate/organisational, project, project portfolio) can be observed. Also, digital communication tools are highly relied upon for transferring relevant knowledge. The involvement of top management in taking initiatives and making strategic decisions in fostering innovation within the organisations and with external parties are clearly visible. In addition, organisation management has provided several platforms to encourage employees (at any level) to

present innovative ideas. Organisations tend to update their knowledge by hiring experts from different countries, observing foreign construction projects and their strategies as well as collaborating with research and academic institutions.

Validation of Framework and Discussion

Having analysed the preliminary interview findings, the research framework is validated. A separate innovation division or a team at organisational/corporate level in contractor organisations shows the structural ambidexterity. The involvement of both project actors and innovation team at head office (corporate/organisational level) in exercising exploration and exploitation at project level shows the contextual ambidexterity. In addition, the use of digital communication tools, monthly meetings and frequent weekly visits made by the head office personnel indicate strong knowledge transfer mechanisms at different levels. Examples for radical innovation (exploration), incremental innovation and continuous development (exploitation) and knowledge transfer have been received from interviewees. Therefore, this study is expected to continue with deep investigations on explorative and exploitative learning within case studies. The findings of case studies on recent innovation in Hong Kong are expected to make valid and reliable suggestions to enhance the innovativeness, efficiency and productivity of the industry. The findings are also expected to contribute to theoretical discourses on exploration and exploitation.

CONCLUSIONS

This study aims at investigating how construction contractor organisations deploy innovation at organisational, project and project portfolio levels through the lens of the learning theory - exploration and exploitation. Radical vs incremental classification of innovation has been linked with this learning theory to explain innovation. The developed research framework suggests both exploration and exploitation can be simultaneously exercised at project and project portfolio levels. Structural separation is required at organisational level.

This study unfolds that contractor organisations in Hong Kong have a positive attitude towards implementing innovation. Despite their active participation, incentives to foster innovation have rarely been provided. Lower profit margin, absence of innovative procurement approach which facilitates collaboration and early involvement of contractor in construction process, and lesser contractual provisions for sharing risks have been highlighted as the innovation-hindering factors for contractors. Innovation in the Hong Kong construction industry is client driven. As the largest client, the role of government to foster innovation is inevitable. The involvement of government is satisfactory, however the necessity of modifying the approval processes has been stressed out. The overall result shows that the Hong Kong construction industry, specially the contractor organisations have realised the necessity of a more innovative and digitalised construction industry. As the next step of this study, these results will be incorporated to conduct case studies to disclose how contractors implement innovation, tangible and intangible benefits, risks and challenges, their strategies to overcome issues, and future intentions to enhance the overall construction process.

REFERENCES

Andriopoulos, C and Lewis, M W (2009) Exploitation-exploration tensions and organisational ambidexterity: Managing paradoxes of innovation, *Organization Science*, 20(**4**), 696-717.

Argote, L (2012) *Organisational Learning: Creating, Retaining and Transferring Knowledge*. New York: Springer Science and Business Media.

Awale, R and Rowlinson, S (2015) An exploratory study of a CSV concept for achieving firm competitiveness in Hong Kong construction firms. *In*: Raiden, A and Aboagye-Nimo, E (Eds.), *Proceedings of the 31st Annual ARCOM Conference*, 7-9 September 2015, Lincoln, UK. Association of Researchers in Construction Management, 947–956.

Benner, M J and Tushman, M L (2003) Exploitation, exploration and process management: The productivity dilemma revisited, *Academy of Management Review*, 28(**2**), 238-256.

Blayse, A M and Manley, K (2004) Key influences on construction innovation, *Construction Innovation*, 4(**3**), 143-154.

Bresnen, M, Edelman, L, Newell, S, Scarbrough, H and Swan, J (2003) Social practices and the management of knowledge in project environments, *International Journal of Project Management*, 21(**3**), 157-166.

Bygballe, L E and Ingemansson, M (2014) The logic of innovation in construction, *Industrial Marketing Management*, 43(**3**), 512-524.

Census and Statistics Department, *The HKSAR (2019) National Income*. Available from https://www.censtatd.gov.hk/hkstat/sub/sp250.jsp?tableID=036&ID=0&productType=8 [Accessed 28th May 2019]

Chan, I Y, Liu, A M and Fellows, R (2013) Role of leadership in fostering an innovation climate in construction firms, *Journal of Management in Engineering*, 30(**6**), 31-37.

Construction Industry Council (2015) *Report on Strategy for Management and Reduction of Construction and Demolition Waste in Hong Kong (August 2017)* http://www.cic.hk/files/page/56/C%26D%20Report_E.pdf [Accessed 28th May 2019].

Damanpour, F and Evan, W M (1984) Organisational innovation and performance: The problem of organisational lag, *Administrative Science Quarterly*, 29(**3**), 392-409.

Development Bureau, The HKSAR (2019) *List of Approved Contractors for Public Works*. https://www.devb.gov.hk/Contractor.aspx?section=80&lang=1 [Accessed 28th May 2019].

Dubois, A and Gadde, L E (2002) The construction industry as a loosely coupled system: Implications for productivity and innovation, *Construction Management and Economics*, 20(**7**), 621-631.

Eriksson, P E and Szentes, H (2014) Organizational ambidexterity in construction projects, *IEEE International Conference on Management of Innovation and Technology*, 81-86.

Eriksson, P E (2013) Exploration and exploitation in project-based organisations: Development and diffusion of knowledge at different organisational levels in construction companies, *International Journal of Project Management*, 31(**3**), 333-341.

Eriksson, P E, Leiringer, R and Szentes, H (2017) The role of co-creation in enhancing explorative and exploitative learning in project-based settings, *Project Management Journal*, 48(**4**), 22-38.

Gherardi, S (1999) Learning as problem-driven or learning in the face of mystery? *Organisation Studies*, 20(**1**), 101-123.

Gibson, C B and Birkinshaw, J (2004) The antecedents, consequences and mediating role of organizational ambidexterity, *Academy of Management Journal*, 47(2), 209-226.

GovHK (2017) *Press Releases: LCQ1: Manpower of Construction Industry*. https://www.devb.gov.hk/en/publications_and_press_releases/press/index _id_9451 html [Accessed 28th May 2019].

Liu, A M and Chan, I Y (2016) Critical role of the learning transfer climate in fostering innovation in construction, *Journal of Management in Engineering*, 33(**3**), 1-10.

March, J G (1991) Exploration and exploitation in organisational learning, *Organization Science*, 2(**1**), 71-87.

Rowlinson, S, Koh, T Y and Tuuli, M M (2010) *Stakeholder Management in the Hong Kong Construction Industry*. Oxford, UK: Wiley-Blackwell.

Slaughter, E S (1993) Builders as sources of construction innovation*, Journal of Construction Engineering and Management*, 119(**3**), 532-549.

Slaughter, E S (1998) Models of construction innovation, *Journal of Construction Engineering and Management-ASCE*, 124(**3**), 226-231.

Tatum, C B (1986) Potential mechanisms for construction innovation, *Journal of Construction Engineering and Management-ASCE*, 112(**2**), 178-191.

Turner, N, Maylor, H, Lee-Kelley, L, Brady, T, Kutsch, E and Carver, S (2014) Ambidexterity and knowledge strategy in major projects: A framework and illustrative case study, *Project Management Journal*, 45(**5**), 44-55.

Tushman, M L and O'Reilly, C A (1996) Ambidextrous organizations: Managing evolutionary and revolutionary change, *California Management Review*, 38(**4**), 8-29.

Van de Ven, A H (1986) Central problems in the management of innovation, *Management Science*, 32(**5**), 590-607.

Winch, G (2003) How innovative is construction? comparing aggregated data on construction innovation and other sectors - A case of apples and pears, *Construction Management and Economics*, 21(**6**), 651-654.

PERFORMANCE MANAGEMENT

THE CONSIDERATE CONSTRUCTORS SCHEME: IMPROVING THE IMAGE OF CONSTRUCTION, BUT HOW CONSIDERATE ARE THEY TO CONTRACTORS?

Michael Curran[1], John P Spillane[2] and Daniel Clarke-Hagan[3]

[1]*School of Natural and Built Environment, David Keir Building, Queens University Belfast, Stranmillis Road, Belfast, BT9 5AG, UK*

[2]*School of Engineering, Schrodinger Building, University of Limerick, Castletroy, Limerick, V94 T9PX, Ireland*

[3]*Department of Engineering and Design, Institute of Technology Sligo, Ash Lane, Sligo, F91 YW50, Ireland*

The United Kingdom (UK) construction industry is fragmented in nature, and frequently attracts hostility among local communities. The concept of Corporate Social Responsibility (CSR) within construction management is relatively new, and the industry is actively engaged in CSR practices. One such approach, and the focus of this paper, is the Considerate Constructors Scheme (CCS). The CCS is an organisation that seeks to improve the image of the construction industry and encourages active engagement with stakeholders. Therefore, this paper aims to identify and document the advantages and disadvantages of registering construction sites with the CCS from a contractor's perspective. This study is part of a broader PhD investigation, concentrating on stakeholder management and engagement. The research method undertaken is qualitatively based, encompassing four case study individual interviews and two focus group seminars, with construction professionals on projects located throughout the UK. The data is qualitatively assessed using mind mapping software and cognitively summarised. Advantages of registering with the Scheme include that CCS principles are applied on all projects anyway, CCS has improved the image of construction sites, CCS is good for the image of the construction industry overall, CCS sets new standards, CCS is good for CSR and, CCS improves relationships with external stakeholders. Disadvantages of registering with the Scheme include having to pay to be a member, the site inspections are varied, the scoring is inconsistent, the CCS is very subjective, you have to pay a lot of money to improve the image of the site, the assessors do not understand the preparation work involved, and there is too much emphasis on irrelevant activities, to gain a high score. The key contribution of this research illustrates many positive and negative attributes, identifying six advantages and seven disadvantages from a contractor's perspective, of registering construction sites with the Considerate Constructors Scheme.

Keywords: Considerate Constructors Scheme, construction image, CSR, stakeholder

INTRODUCTION

The United Kingdom (UK) construction industry frequently attracts hostility among the local community and public, due to its disruptive influence arising from

[1] mcurran23@qub.ac.uk

Curran, M, Spillane, J P and Clarke-Hagan, D (2019) The Considerate Constructors Scheme: Improving the Image of Construction, But How Considerate Are They to Contractors? *In:* Gorse, C and Neilson, C J (Eds) *Proceedings of the 35th Annual ARCOM Conference,* 2-4 September 2019, Leeds, UK, Association of Researchers in Construction Management, 609-618.

construction and demolition activities (Othman 2009; Barthorpe 2010). These activities impact areas surrounding construction sites and affect a wide range of stakeholders (Glass and Simmonds 2007). Considering the fragmented nature of urban construction projects, Curran *et al.,* (2018) suggest that integration and communication is required amongst all stakeholders. As a result, Lin *et al.,* (2018) acknowledge that implementing social responsibility at construction project level is crucial for achieving sustainable development within the construction industry. The concept of Corporate Social Responsibility (CSR) within construction management is relatively new (Larsen *et al.,* 2012), and it is aimed at improving construction processes in its broadest terms. Other scholars (Watts and Holme 2003; Loosemore and Lim 2017a) generally describe CSR as the continuing commitment by business, to behave ethically and contribute to economic development, while improving the quality of life of the workforce and their families, as well as of the local community and society at large. Loosemore and Lim (2017b) argue that the construction industry is adopting an integrative approach to CSR, recognising the mutuality of interests between business and society. Furthermore, Barthorpe (2010) and Larsen *et al.,* (2012) corroborate that the construction industry in the UK is actively engaged in CSR practices. One such practice is the Considerate Constructors Scheme (CCS), which is an organisation that seeks to improve the image of the construction industry and encourages active engagement with stakeholders and the local community (CCS 2018a). Construction sites and companies voluntarily register with the Scheme and agree to abide by a Code of Considerate Practice.

When reviewing the literature, previous research fails to acknowledge and highlight the advantages and disadvantages of registering with the CCS from a UK contractor's perspective, while most industry reports and surveys appear vague in comparison. Therefore, in the context of urban construction sites, it is necessary to identify an understanding of contractor's attitudes towards the CCS, both positive and negative, and what advantages and disadvantages there are, if any, from registering a construction site with the Scheme. To address these issues and fulfil a gap in knowledge, it is essential to consider and generate results based on actual events that emerge, when studying an inherently complex environment, such as the UK construction industry. Concentrating on a pertinent angle of interest, these aims are achieved by implementing a sequential mixed method approach, assimilating a combination of qualitative techniques for analysis, including a literature review and semi-structured individual interviews and focus group seminars, while using mind mapping software, which can be cognitively summarised. In addressing this aim, it is anticipated that this study will assist and aid contracting companies in identifying advantages and disadvantages of registering their construction sites with the CCS.

THE CONSIDERATE CONSTRUCTORS SCHEME

In the UK, following recommendations emanating from the seminal Latham Report (1994), the Considerate Constructors Scheme (CCS) was founded (Barthorpe *et al.,* 2004). The report concluded that the construction industry should implement and extend the Corporation of London's 'Considerate Contractors Scheme', launched in 1987 (Ogunlana 2003), and the City of Westminster's 'Considerate Building Scheme', launched in 1989 (Murray *et al.,* 2011), across the rest of the UK, with immediate effect. Following this report, the Construction Industry Council (CIC) were tasked with building on the success of these models and improving the image of the industry, and, as a result of its work, the CCS was formed (Designing Buildings 2018). Oyedele (2012) argues that the Scheme is concerned with any area of construction

activity that may have a direct or indirect impact on the image of the industry. Mackenzie *et al.,* (2000) agree that its aim is to outlaw unsafe and untidy construction sites and improve the standard of site management and the behaviour of site operatives.

The Scheme operates a voluntary Code of Considerate Practice (Lou *et al.,* 2012; 2015), committing those in the Scheme to "care about appearance, respect the community, protect the environment, secure everyone's safety and value their workforce" (CCS 2018a). Murray *et al.,* (2011) support that one of the key requirements of the CCS, is to establish contact with neighbours who are affected by the project and maintaining communication from pre-start to completion. Since its inception in 1997, over 100,000 sites all over the UK have registered with the Scheme (CCS 2018b), and in 2017, it registered its first site in Ireland (Construction News 2017). Barthorpe (2003) highlights that the CCS is an ideal framework for the construction industry to implement a societal stakeholder approach; however, Glass and Simmonds (2007) argue that to improve the sometimes-difficult relationship between construction and its stakeholders, more research on effective practices is required. Nevertheless, the CIOB (2010) affirm that initiatives such as the CCS encourage various campaigns and techniques, to enhance project communications to a wider range of stakeholders. Barthorpe (2010) further supports that the introduction of the CCS has provided a useful framework and impetus for construction companies and their clients, to carefully consider their community stakeholders and raise their social and environmental awareness performance. Thus, by registering a site with the CCS, a construction company is openly demonstrating their commitment to CSR, and promotion of good practice (CCS 2003).

RESEARCH METHOD

This study is part of a broader investigation within a PhD, concentrating on stakeholder management and engagement within UK and Irish urban construction projects. Considering the theoretical position and epistemological reasoning this paper and subsequent research is founded on, a critical realism approach is used. A subjectivist approach is applied to the ontology, as the nature of this study primarily deals with the opinions of human participants, which also provides a basis for the case study methodology. On completion of an informative literature review, the research method consists of case study analysis, including four exploratory individual interviews and two focus group seminars, with a variety of construction professionals based on large urban development projects situated throughout the UK. The selection of the six case studies was based on a combination of criterion and convenience sampling strategies; firstly, by identifying construction sites that were registered with the CCS, and secondly, by arranging interviews and focus groups depending on the participants availability at the time of each visit. The unit of study incorporates both individuals and groups, as De Vaus (2002) states that the research problem can be approached from a variety of angles. Similarly, the case study approach is chosen as it is the most suitable for the 'how' and 'why' research questions (Yin 2014), which Rowley (2004) believes is beneficial as it facilitates the investigation of a phenomenon in its real-life context. Also, a semi-structured interview format is chosen, as this uses an open and closed ended form of questioning, where questions are asked in no specific order or schedule (Naoum 2007). This method allows questions to lead from one to another, enabling the interviewee to provide as much information as possible. Considering the focus group seminars, Guest *et al.,* (2017)

surmise that this method allows for the production of information that might not be gathered from a single respondent.

Considering ethical issues, each participant was informed of the nature of the research, its purpose, and what the resultant data will be used for. The identities of those involved remain anonymous, and confidential information such as company names, addresses, client details, etc. are not disclosed. Case A consists of a new £500 million mixed use development in London, and the interviewee is a Community Liaison Manager with ten years' industry experience, working for the main contractor, which is a very large international firm. Case B is another mixed used development in London, valued at £34 million, and the interviewee is a Site Manager with seven years' experience, working for the main contractor, which is based in Ireland. Case C is a new £850 million sports stadium development in London, and the interviewee is a Community Engagement Manager with fourteen years' experience, working for the main contractor, which is a very large international firm. Case D is a new £30 million student accommodation complex in London, and the interviewee is a Project Manager with ten years' experience, working for the main contractor, which is based in Northern Ireland. Case E is a new £9.2 million hotel development in London, and the interviewees are a Project Manager with eighteen years' experience, and a Health and Safety Manager with over thirty years' experience, working for the main contractor which is based in Ireland. Finally, Case F is a £16 million secondary school development in Northern Ireland, and the interviewees include a Community Liaison Manager, Facilities Manager, Health and Safety Officer, Quantity Surveyor and Contracts Manager with an average of thirty years' industry experience, working for the main contractor which is a medium sized contracting company based in Northern Ireland. The six case studies are a combination of both live and recently completed urban development projects. All four interviews and two focus groups were recorded in handwritten note format, and interaction with the participants on Cases A, B, C and E took place in the site offices of each project, whereas Cases D and F took place in the company's head offices.

QUALITATIVE ANALYSIS AND RESULTS

The interviews and focus groups commenced by gaining general background information about each participant and their relevant case study. This was followed by a discussion of the advantages and disadvantages of the CCS from their own perspective. The data gathered from the case study interviews and focus groups is then qualitatively assessed and cognitively summarised using mind mapping software. Banxia Decision Explorer® is used for this purpose, which builds a visual representation of ideas and can provide a focus for debate, reflection and progression. Marin and Wellman (2011) note that this form of analysis is also known as social network analysis, as it involves the use of a network diagram which connects socially-relevant nodes by one or more relations. Decision Explorer® can undertake many forms of analysis, but for the purposes of this study, Central and Domain Analysis is used. The analysis logically expresses how each factor or 'concept' is linked and interpreted, and each concept was discussed in some form by the interviewees. Central Analysis presents the key concepts from the interviews which have the greatest effect or impact on the mapped model (Brightman 2002), and the higher the score, the higher the effect that concept has on the map. Domain Analysis shows concepts which have many links, giving a representation and an understanding of relationships that exist in the mapped model (Montazemi and Conrath 1986). Due to space limitations, only the top five concepts in the Central and Domain Analysis,

including advantages and disadvantages of both are included. Combining the data from all four interviews and two focus groups, the key concepts are illustrated in Tables 1 and 2. It is worth noting that the findings are case study specific, thus, not a generalised view. However, this study provides a foundation to advance and explore the topic further, supporting continuous research into the Considerate Constructors Scheme and its role in the UK construction industry.

Table 1: Central Analysis

Rank	Score	Concept (Positives / Advantages)
1	27 from 50 concepts	Many CCS principles already applied on projects anyway
2	26 from 50 concepts	The CCS is good for the image of the construction industry overall
3	26 from 49 concepts	The CCS has improved the image of construction sites
4	22 from 45 concepts	The CCS is good for CSR
5	20 from 46 concepts	The CCS improves relationships with external stakeholders
Rank	Score	Concept (Negatives / Disadvantages)
1	24 from 49 concepts	You have to pay to be a member (of the CCS)
2	23 from 46 concepts	The site inspections are varied
3	22 from 46 concepts	You have to pay a lot of money to improve the image of your site
4	21 from 45 concepts	The scoring is inconsistent
5	21 from 42 concepts	The CCS is very subjective

Table 2: Domain Analysis

Rank	Number of Links	Concept (Positives / Advantages)
1	5	Many CCS principles already applied on projects anyway
2	4	The CCS has improved the image of construction sites
3	4	The CCS is good for the image of the construction industry overall
4	3	The CCS sets new standards
5	3	The CCS is good for CSR
Rank	Number of Links	Concept (Negatives / Disadvantages)
1	5	Too much emphasis on irrelevant activities to gain a high score
2	3	You have to pay to be a member (of the CCS)
3	3	The assessors do not understand the preparation work involved
4	3	You have to pay a lot of money to improve the image of your site
5	2	The CCS is very subjective

DISCUSSION

Positives and Advantages

Combining the four case study interviews and two focus groups, the data explores the experiences of construction contractors who register their sites with the CCS. The top concept from both the Central and Domain Analysis is 'many CCS principles already applied on projects anyway'. This was frequently discussed in four of the case studies and corroborates with an annual survey carried out by the CCS in 2012, where they found that 53% of contractors surveyed said they already implement similar practices (CCS 2012). The Community Liaison Manager in Case F remarked that the company would always try to implement considerate practice on all projects, even if they were not contractually obliged to. Rok *et al.,* (2017) support that CSR is used to describe everything that a company does, aside from what it has always done, to satisfy stakeholders further. The Contracts Manager in Case F recognised the principles

behind the CCS but stressed that it is a matter of applying some common sense. This substantiates with Ogunlana (2003), who suggests that being socially responsible, by applying considerate contracting techniques, was not altruism, but sound business sense. Also, the Project Manager in Case D echoed that on his site, the construction team assisted the local church in building a wall and tidying up the area, as a gesture of goodwill. They also held a coffee morning on site, to raise money for a local charity, as he believed that small acts like that make a positive impact on the local area. Sözen and Kayahan (2001) argue that goodwill is the most effective and least costly means of safeguarding exchange and enhancing performance. Lau and Rowlinson (2009) also agree, stating that using goodwill gestures demonstrates a willingness to invest in high levels of trust, credibility and reputation.

The findings in both the Central and Domain Analysis are closely linked, with the next concepts identified as 'the CCS is good for the image of the construction industry overall', 'the CCS has improved the image of construction sites', 'the CCS is good for CSR', 'the CCS improves relationships with external stakeholders', and 'the CCS sets new standards'. All interviewees did agree that the CCS was good for the industry, and its image has improved since its inception. Geach (2016) argues that the CCS has encouraged a paradigm shift, in which construction companies aim to increasingly care about the environmental performance of the buildings they build and leave positive legacies in the communities they work in. Also, Murray and Dainty (2013) suggest that the desire of the construction firm to project a positive and responsible image to its customers is rooted in its business practices. Furthermore, the CCS Annual Survey 2012 supports that for clients and contractors, the biggest benefit of the CCS is that it creates better relations between the construction industry and the public (CCS 2012). Regarding CSR, the Project Manager in Case F believed that the CCS is something that keeps a construction company focussed in being socially responsible, and it is their duty to consider all stakeholders on the project, both internal and external. Barthorpe (2010) argues that CSR can be considered as an umbrella term, incorporating the tenets of environmental sustainability, business ethics, public relations and stakeholder analysis. Ghobadian *et al.,* (2015) agree that CSR has become a widely used term for a variety of stakeholders, with a desire to rethink traditional ways of doing business. The Site Manager in Case B felt that being registered with the CCS did benefit their relationship with external stakeholders in the local community, as Li *et al.,* (2013) note that failure to accommodate external stakeholder concerns in large construction projects can lead to severe resistance.

Negatives and Disadvantages

Two of the main concepts in both the Central and Domain Analysis are related to costs; 'you have to pay to be a member (of the CCS)', and 'you have to pay a lot of money to improve the image of your site'. This was discussed frequently in four of the case studies and supports the findings of the CCS 2012 Annual Survey, which showed that the cost of registration was the least satisfactory part of the Scheme (CCS 2012). Caven *et al.,* (2016) argue that one of the weaknesses of the Scheme is that it is funded by its member organisations to outsource their own responsibility for monitoring behaviours. The Community Engagement Manager in Case C empathised the difficulties a smaller contracting firm face when trying to fulfil a number of CCS requirements. In the large company she works for, there are more finances and resources to employ a Sustainability Manager and Community Engagement Manager, to complete the various CCS related tasks. The focus group participants in Case F asserted this view, arguing that the fee to register with the CCS is quite expensive, and

extra costs are incurred for posters and other branded materials. One of the participants exclaimed further that the CCS is 'a money-making racket!'

The first and third concepts in the Domain Analysis is 'too much emphasis on irrelevant activities to gain a high score', and 'the assessors do not understand the preparation work involved'. The Site Manager in Case B was sceptical of the CCS, stating that it can be onerous and tedious to hit the targets that they set, and that the people setting these standards, have very little experience of actually being on site. The Community Liaison Manager in Case A agreed that she did not think the CCS assessors understood the amount of work involved in preparing for a site visit, in the hope of gaining a high score. Murray *et al.,* (2011) validate that the Scheme is always looking for the contractor to be inventive and imaginative, as well as being a proactive, accountable good neighbour and employer. Abuzeinab and Arif (2014) support that the desire to get a good CCS score has encouraged site managers to engage in finding innovative ways to improve the main categories covered by the Scheme. One example of this is planting flowers. The Project Manager in Case D spoke about how his company planted flowerbeds for a local community group adjacent to the site, and the Health and Safety Manager in Case E spoke about using old hard hats as a substitute for flower baskets, which were placed at the site entrance. The Contracts Manager in Case F argued that flowers may look pleasant but questioned what they have got to do with the actual construction project itself. Nevertheless, Woodhead (2015) stress that it is the little things that count and planting a small flowerbed at a site entrance can be the difference between a good score and an excellent score.

The remaining concepts in the Central and Domain Analysis are associated with the inconsistency of the scoring and site inspections; 'the site inspections are varied', 'the scoring is inconsistent', and 'the CCS is very subjective'. This was a recurring theme across five of the case studies, and a significant issue amongst the participants. The Project Manager in Case D argued that the scoring system is very subjective, citing that another construction site in another part of the country, where the company is the main contractor, will gain a higher score for the same or maybe less preparation work carried out on his site. The Health and Safety Officer in Case F had similar experiences. As he was the main person within the company overseeing CCS across all company projects, he ensured that all sites had the same standards in place, but commonly found that a CCS monitor would give varying scores for the same requirements. The consistency in monitor's scoring was one of the least satisfactory elements of the Scheme according to a CCS Survey in 2012, where smaller firms felt they were being judged according to the same criteria as larger and wealthier sites, putting them at a disadvantage (CCS 2012).

CONCLUSION AND RECOMMENDATIONS

This study focuses on identifying advantages and disadvantages of registering construction sites with the Considerate Constructors Scheme (CCS) from a UK contractor's perspective. The UK construction industry is fragmented in nature and frequently attracts hostility among the local community and public. The concept of Corporate Social Responsibility (CSR) aims at improving construction processes in its broadest terms, and the UK industry is actively engaged in CSR practices, with one such practice being the CCS. Considering the results captured from the case studies and data analysis, including four individual interviews and two focus group seminars, six advantages and seven disadvantages are identified. Advantages of registering with

the Scheme include; that 'CCS principles are applied on all projects anyway', 'CCS has improved the image of construction sites', 'CCS is good for the image of the construction industry overall', 'CCS sets a standard', 'CCS is good for CSR' and 'CCS improves relationships with external stakeholders'. Disadvantages of registering with the Scheme include; 'having to pay to be a member', 'the site inspections are varied', 'the scoring is inconsistent', 'the CCS is very subjective', 'you have to pay a lot of money to improve the image of the site', 'the assessors do not understand the preparation work involved', and 'there is too much emphasis on irrelevant activities to gain a high score'.

However, the findings from the interviews and focus groups are case study specific, and only a concise, subjective view of the topic is produced, not a generalised one. Nevertheless, this study provides a foundation to advance and expand into more detailed research and supports continuous investigation into the role of the CCS. The findings in this paper can be developed further, and it is anticipated that a wider analytical context can be addressed in an ensuing journal publication, where additional theoretical points of departure can be articulated. It is recommended that further case studies in the form of both individual interviews and focus group seminars are considered for qualitative analysis, and a sequential selection strategy is incorporated using quota and random sampling methods. Therefore, this provides the basis for informing and verifying the validity and necessity of the research and subsequent investigation going forward. Furthermore, additional case studies that are qualitatively considered can be developed quantitatively using questionnaire surveys, introducing another aspect to the area of research. To summarise, this study illustrates to construction contracting firms that there are both positive and negative attributes with registering construction sites with the Considerate Constructors Scheme, including six advantages and seven disadvantages identified in this research.

REFERENCES

Abuzeinab, A and Arif, M (2014) Stakeholder engagement: A green business model indicator, Procedia *Economics and Finance*, 18, 505-512.

Barthorpe, S (2003) Enhancing project performance by implementing a societal stakeholder culture. *In*: Uwakweh, B O and Minkarah, I A (Eds.) *The Organisation and Management of Construction: Proceedings of the 10th International Symposium, Construction Innovation and Global Competitiveness Volume 2*, CRC Press, 948-59.

Barthorpe, S (2010) Implementing corporate social responsibility in the UK construction industry, Property *Management*, 28(**1**), 4-17.

Barthorpe S, James, R and Taylor, S (2004) Corporate social responsibility: An imperative or imposition upon the UK construction industry? 2nd - 7th May, *CIB World Congress*, Toronto, Canada.

Brightman, J R (2002) *An Introduction to Decision Explorer*. Cumbria: Banxia Software Ltd.

Caven, V, Navarro-Astor, E and Diop, M (2016) A cross-national study of gender diversity initiatives in architecture: The cases of the UK, France and Spain, *Cross Cultural and Strategic Management*, 23(**3**), 431-449.

CCS (Considerate Constructors Scheme) (2003) *Corporate Social Responsibility*. Available from https://www.ccscheme.org.uk/corporate-social-responsibility/ [Accessed 4/07/2019].

CCS (Considerate Constructors Scheme) (2012) *Annual Survey 2012*. Available from https://www.ccscheme.org.uk/wp-content/uploads/2012/03/2012-survey-report2.pdf [Accessed 4/07/2019].

CCS (Considerate Constructors Scheme) (2018a) *Code of Considerate Practice*. Available from https://www.ccscheme.org.uk/ccs-ltd/code-of-considerate-practice-2/ [Accessed 4/07/2019].

CCS (Considerate Constructors Scheme) (2018b) *History of the Considerate Constructors Scheme*. Available from https://www.ccscheme.org.uk/ccs-ltd/history-css-ltd/ [Accessed 4/07/2019].

Construction News (2017) *Considerate Constructors Signs Up First Irish Site*. Available from https://www.constructionnews.co.uk/news/archive-news/considerate-constructors-signs-up-first-irish-site-17-05-2017/ [Accessed 4/07/2019].

CIOB (Chartered Institute of Building) (2010) *Code of Practice for Project Management for Construction and Development 4th Edition*, Oxford, UK: Wiley-Blackwell.

Curran, M, Spillane, J and Clarke-Hagan, D (2018) External stakeholders in urban construction development projects: Who are they and how are they engaged? *In*: Gorse, C and Neilson, C J (Eds.) *Proceedings of the 34th Annual ARCOM Conference*, 3-5 September, Belfast, UK, Association of Researchers in Construction Management, 139-148.

De Vaus, D (2002) *Research Design in Social Research*. London: Sage Publications.

Design Buildings (2018) *Considerate Constructors Scheme CCS*. Available from https://www.designingbuildings.co.uk/wiki/Considerate_Constructors_Scheme_CCS [Accessed 4/07/2019].

Geach, I (2016) *Investigating the Role of Sustainability in Contractor Selection and Validation*. London: Chartered Institute of Building (CIOB).

Ghobadian, A, Money, K and Hillenbrand, C (2015) Corporate social responsibility research: Past-present-future, *Group and Organization Management*, 40(**3**), 271-294.

Glass J and Simmonds M (2007) Considerate construction: Case studies of current practice. *Engineering, Construction and Architectural Management*, 14(**2**), 131-149.

Guest, G, Namey, E, Taylor, J, Eley, N and McKenna, K (2017) Comparing focus groups and individual interviews: Findings from a randomized study, *International Journal of Social Research Methodology*, 20(**6**), 693-708.

Larsen, G, Phua, F T and Kao, C C (2012) Understanding the long-term success of UK construction firms: The extent and role of 'hidden' corporate social responsibility, *Joint CIB W70 International Conference: Delivering Value to the Community,* 23rd - 25th January, Cape Town, South Africa.

Latham M (1994) *Constructing the Team, Final Report of the Joint Government / Industry Review of Procurement and Contractual Arrangements in the United Kingdom Construction Industry*. London: HMSO.

Lau, E and Rowlinson, S (2009) Interpersonal trust and inter-firm trust in construction projects, *Construction Management and Economics*, 27(**6**), 539-554.

Li, T H, Ng, S T and Skitmore, M (2013) Evaluating stakeholder satisfaction during public participation in major infrastructure and construction projects: A fuzzy approach, *Automation in Construction*, 29, 123-135.

Lin X, Ho, C M F and Shen, G Q (2018) For the balance of stakeholders' power and responsibility: A collaborative framework for implementing social responsibility issues in construction projects, *Management Decision*, 56(**3**), 550-569.

Loosemore M and Lim B T H (2017a) Mapping corporate social responsibility strategies in the construction and engineering industry, *Construction Management and Economics*, 36(**2**), 67-82.

Loosemore M and Lim B T H (2017b) Linking corporate social responsibility and organisational performance in the construction industry, *Construction Management and Economics*, 35(**3**), 95-105.

Lou, E C, Lee, A and Mathison, G (2012) Corporate Responsibility Application - UK Construction SME, *International Journal of E-Education, e-Business, e-Management and e-Learning*, 2(**5**), 436.

Lou, E C, Lee, A, Song, W and Mathison, G (2015) Responsible Construction? *International Journal of Sustainable Strategic Management*, 4(**4**), 342-358.

Mackenzie, S, Kilpatrick, A R and Akintoye, A (2000) UK construction skills shortage response strategies and an analysis of industry perceptions, *Construction Management and Economics*, 18(**7**) 853-862.

Marin, A and Wellman, B (2011) *Social Network Analysis: An Introduction: The SAGE Handbook of Social Network Analysis*. London: Sage Publications Ltd.

Montazemi, A R and Conrath, D W (1986) The use of cognitive mapping for information requirements analysis, *MIS Quarterly*, 45-56.

Murray, M and Dainty, A (2013) *Corporate Social Responsibility in the Construction Industry*. Abingdon: Routledge.

Murray, M, Forbes, D and Mason, S (2011) Considerate Constructors Scheme: Glenfarg water treatment works, *Proceedings of the ICE-Engineering Sustainability*, 164(**1**), 49-57.

Naoum, S G (2007) *Dissertation Research and Writing for Construction Students 2nd Edition*. Oxford: Butterworth-Heinemann.

Ogunlana S (2003) *Profitable Partnering in Construction Procurement*. Abingdon: Routledge.

Othman, A E (2009) Corporate social responsibility of architectural design firms towards a sustainable built environment in South Africa. *Architectural Engineering and Design Management*, 5(**1-2**), 36-45.

Oyedele, O A (2012) Public-Private Partnership (PPP) and Infrastructure Provision in Nigeria. *In*: A*ARCHES 2012 Biennial General Meeting and Annual Conference*.

Rok, B, Fabrycka, W, Minasowicz, A, Nowak, P and Zaleski, J (2017) *Corporate Social Responsibility in Construction*. Construction Managers' Library, Warsaw University of Technology, Poland.

Rowley, J (2004) Researching people and organizations, *Library Management*, 25(**4**), 208214.

Sözen, Z and Kayahan, O (2001) Correlates of the length of the relationship between main and specialist trade contractors in the construction industry. *Construction Management and Economics*, 19(**2**), 131-133.

Watts P and Holme L (2003) *Corporate Social Responsibility*. World Business Council for Sustainable Development, Conches-Geneva: Switzerland.

Woodhead, C (2015) *Top Ten Tips for CCS Success.* Available from http://woodhead-construction.co.uk/top-ten-tips-for-ccs-success/ [Accessed 4/07/2019].

Yin, R K (2014) *Case Study Research: Design and Methods 5th Edition*. Thousand Oaks, CA: Sage Publications.

DOMINO EFFECT OF ADVANCE PAYMENT ON PROJECT CASH FLOW AND ORGANISATION PERFORMANCE

Emmanuel Dele Omopariola[1] and Abimbola Olukemi Windapo[2]

[1] *Department of Construction Economics and Management, Snape Building, Upper Campus, University of Cape Town, Rondebosch, 7701, Cape Town, South Africa*

[2] *Department of Construction Economics and Management, Snape Building, Upper Campus, University of Cape Town, Rondebosch, 7701, Cape Town, South Africa*

The adverse effect of late payment by employers or contractors and consultants is a common phenomenon and a costly problem in the construction industry. This paper examines the domino effect of the advance payment of contractors on project cash flow and company performance. This stems from the view held by scholars that smooth cash flow guarantees the efficient delivery of construction projects and is a basis for developing and maintaining a healthy and competitive construction industry. The study employs a systematic review of extant literature and a quantitative research approach. A questionnaire survey of construction firms listed in Grade 7 to 9 on the Construction Industry Development Board (CIDB) Register of Contractors was conducted to acquire information required to address the research objective. Using this approach, the study first formulated a conceptual framework and hypothesised relationships illustrating the domino effect of the advance payment system (APS) on project cash flow and organisation performance based on literature review. The effect of the advance payment system and relationship between it, project cash flow and organisation performance were evaluated using a structured questionnaire. After that, the data collected were analysed using mean score and t-test. The findings of this study indicated that APS has no effect on project cashflow and performance of organisations and projects, which negates the hypothesised relationships that were identified in the conceptual framework. The study concludes that the use of APS on projects is not widespread among South African contractors, explaining why the effect of APS on cash flow and organisation was non-significant as against the conclusions of past studies.

Keywords: Advance payment, cash flow, domino theory, organisation performance

INTRODUCTION

A reliable payment system facilitates the performance in construction projects. For a construction project to be a success, it must be funded well (Aje *et al.,* 2017). The contractor's success relies upon being able to hand over the construction project when it has been completed because all the payments due for the construction project are paid at the right time (Oke *et al.,* 2013). Researchers in construction management, such as Kenley (2003), Motawa and Kaka (2008), Omopariola and Windapo (2018), have investigated how payment systems impact project and organisation performance.

[1] ompemm002@myuct.ac.za

Omopariola, E D and Windapo, A O (2019) Domino Effect of Advance Payment on Project Cash Flow and Organisation Performance *In:* Gorse, C and Neilson, C J (Eds) *Proceedings of the 35th Annual ARCOM Conference,* 2-4 September 2019, Leeds, UK, Association of Researchers in Construction Management, 619-628.

Previous research by Omopariola and Windapo (2018), Wong *et al.,* (2006), and Motawa and Kaka (2008) established that the payment systems currently in use include interim payment, advance payment, stage payment, milestone payment and payment on completion. The governing principle underlying these systems is that clients make payments to contractors in different ways.

An example is making payments periodically to contractors as work on site progresses, based on a review of the estimated value of the work carried out by the contractor, known as the interim payment method. The sum of money usually paid to the contractor by the client before the commencement of the work is described as mobilisation and advance payment. Another method is payment made at the time of completion of the project. This means that each of these methods infers different cashflow situations that could be considered in different ways.

According to Odeyinka *et al.,* (2008), project cash flow is said to be the actual movement of cash (money) in and out of a construction company. The generation of project cash flows is vital for client and contractor. Cash flow is key, especially to the project execution period, due to its usage in assessing the working capital requirements, since the difference between project outflows and payments determines the required capital reserves (Lowe, 1997; Maravas and Pantouvakis, 2012). Also, the specification of project finance requirements and the analysis of the value earned by the capital, and the task of conducting a cost-benefit analysis of the project, are all derived from the actual project cash flow (Maravas and Pantouvakis, 2012). In short, the sub-set of cash flow for the construction organisation is the construction project cash flow (Odeyinka and Kaka, 2005). Payment made to suppliers, sub-contractors and direct costs is dependent on cash inflows from the client. These payments follow the different contracts and agreements between the contractor and client, subcontractors and suppliers, as well as a basis if labour and materials are called up for use during the project execution stage (Kenley, 2003; Odeyinka and Kaka, 2005). In conclusion, the progress of a construction project is reliant on its project cash flow, which serves as a key factor that affects construction company's profitability (Hwee and Tong, 2002).

The poor performance of construction projects and organisations in the construction industry is a global phenomenon. The delivery of successful quality projects and the ability to meet client requirements and resolve disputes between stakeholders is often affected by inappropriate payment systems in the construction industry. Danuri *et al.,* (2006) see payment as the main subject of disputes that lead to financial problems among construction stakeholders, resulting in arbitration and litigation. The client's choice of payment systems is not appropriately aligned to the project environment, while previous researchers (Odeyinka and Kaka, 2005) have revealed that contractors have been dissatisfied with the payment systems used, due to the problems they create, as different systems affect their cash flow during the implementation of the construction project. Davis Langdon and Seah Consultancy (2000) posited that construction project payment difficulties have a domino effect on the supply chain of a construction project. The delay in the payment to the contractor by the client will affect the payment due to the subcontractor or supplier, who is bound in a contract with the construction firm (Odeyinka and Kaka, 2005; Egan, 1998). Also, due to the way the construction company supply chain was designed and structured, failure in the flow of cash, such as payment from the employer to the contractor, hinders the effective delivery of the project, resulting in construction firm liquidation (Odeyinka

and Kaka, 2005). This, in turn, would impact the organisation performance of the construction firms.

An effective payment method, adequate cash flow management and a sound financial management approach stimulate performance in construction operations (Arditi *et al.,* 2017; Lowe, 1997). However, researchers have seldom determined the domino effect of advance payment on the project cash flow and construction organisation performance. This study will fill this gap in knowledge. This research examines whether advance payment affects organisation performance, through project cash flows. Thus, the study will present a literature review on domino theory, the effect of advance payment on project cash flow, and construction company performance. Thereafter, it outlines the research methodology used, and presents the findings and conclusion.

Theoretical Framework and Hypothesis Formulation

Theoretical framework

Domino theory has been successfully applied to the field of financial management and construction company performance (Lowe, 1997). The theory states that the failure of a firm is likely to cause another firm to become insolvent (Mutti and Hughes, 2002; Lowe and Moroke, 2010). The domino effect occurs when a client owes the contractor a considerable sum of money and is unable to pay the contractor when payment is due (Langdon and Seah Consultancy, 2003; Lip, 2003; Nicholas, 2005). The contractor's inability to meet up their financial commitment to the sub-contractors will result in the insolvency of both their own company and that of the sub-contractor (Lowe, 1997). Furthermore, as argued by Withanachi and Fernando (2013) and Choil and Kim (2014), when a contractor or client is unable to obtain a credit facility from their financial institution, this could trigger a domino effect and result in poor organisational performance. According to Hughes *et al.,* (1994), when the main contractor transfers risk to their sub-contractors in the process of protecting their interests, this could result in a domino effect on the work of other sub-contractors. Grosse-Ruyken *et al.,* (2011) and Nicholas and Edwards (2003) posited that the domino effect of sub-optimum working capital management results in financial hitches at a lone supplier in the supply chain, and even liquidation. Grosse-Ruyken *et al.,* (2011) concluded that each working capital management decision should reflect each upstream and downstream partner within the supply chain in the construction industry. Consequently, the inadequacy of working capital and the in- and outflow of cash is of concern, as it can, in extreme situations, drive effective and lucrative companies into insolvency (Lowe and Moroke, 2010). Thus, Choil and Kim (2014) propose that an investigation of the management features, (payment systems, financial management strategies, and organisational performance) of a construction company is of importance to its survival.

Hypothesis Formulation

Effects of advance payment on project cash flow

Cash flow problems are recurrent issues with contractors in emerging countries (Talagala, 1997). In respect of this, an important aspect of the relationship between employer and the construction firms is for employers to pay contractors in advance at least once, most commonly at the commencement of a contract (Aje *et al.,* 2017). Consequently, contractors and sub-contractors are paid in advance by clients to support the contractors in initiating and sustaining robust cash flows at one stage of the project contracts or the other (Abeysekera, 2002; Rameezdeen *et al.,* 2006).

Construction projects demand a high quantity of capital for their actualisation (Wang, 1984). According to Jaafari (1996), cash flow is vital to the contractor; any interruption of the payment will affect cash flow and cause the contractor problems in financing other work (Oke *et al.,* 2013). Not to disrupt the progress of construction projects calls for the need to advance capital to the contractor to facilitate payment to sub-contractors, suppliers, and labour. An advance payment offers the contractor an interest-free loan during the early stage of the contract where the greatest strain is placed on a contractor's cash flow (Oke *et al.,* 2013). Besides, providing advance payment to the contractor will make the construction company more effective in meeting the final cost of the project, as well as the final cost and duration required by the client, instead of contractors delaying the project by trying to obtain a loan externally.

Further evidence exists in the research carried out by Berends and Dhillon (2004) that shows how advance payments are made for large engineering works. Talagala (1997) has also described how advance payments are administered in Sri Lanka and China. While Aje *et al.,* (2017) and Jagboro (1998) have also worked on overrun causations under advance payment regimes, and the net present value of payments made in advance for construction materials in Nigeria; these instances underscore the importance of advance payments to the operations of Nigerian construction companies. These studies made advance payment goals clear: Advance payment enables contractors to establish the client's commitment to project finance and cash flow, and clients can commit contractors to appropriate performance.

Ultimately, the client's strategic goal in paying contractors in advance is to anticipate cash needs for resources so that contractors can pay for scarce resources before the prices rise (Aje *et al.,* 2017), and to avoid the accruable costs that could ultimately add to the client's project costs (Spackman, 2002). As a result, advance payment is described as a strategy to lower projects' outturn costs and helps to speed up the progress of work, prevent delay and guarantee the quality of work, to attain efficiency and profitability. Based on this background the first hypothesis (H1) is formulated.

H1: The advance payment system has a significant effect on project cash flow.

Effect of advance payment on organisation performance

Researchers have given several different explanations for advance payments (Aje, *et al.,* 2017; Oke *et al.,* 2013; Motawa and Kaka, 2009). Project finance literature has identified an advance payment system as one of the significant factors that influence project success (Li *et al.,* 2005). Similarly, other significant studies show that advance payment relates to strategic and statutory practices that facilitate project success. Jagboro (1998) highlights that advance payment serves as a strategic value in the Nigerian construction business environment. This is because advance payment made for materials helps to evade the price fluctuation that usually serves as a reason for cost overrun in construction projects. The establishment of client commitment to contractors with project finance aids the prompt performance of the contractor on construction project operations (Aje *et al.,* 2017). However, effective completion of a construction project relies mainly on how valuable advance payment is to different construction projects. In the previous research (see Oke *et al.,* 2013), it was established that advance payment prompts the completion of the construction project within the specified time and enables the contractors to compete more efficiently in the global market. This corroborates the study carried out by Omopariola and Windapo (2018) that advance payment guarantees efficiency and profitability of

project and organisation performance. As such, advance payment to contractors from the client catalyses the successful completion of construction projects by the construction company (Ellis, 1991). This argument leads to the second hypothesis (H2).

H2: The advance payment system has a significant effect on organisation performance.

The conceptual framework of the effect of advance payment on project cash flow and construction organisation performance

Based on the theoretical framework and hypothesised relationships identified in the above section, a conceptual framework is developed. Figure 1 presents a conceptual framework on the effect of advance payment on project cash flow and construction organisation and project performance. Figure 1 shows the domino effects of APS on cash flow, and organisation and project performance. The domino effect of APS on cash flow includes robust and interest-free cashflows, non-disruption of project progress, prompt payment of sub-contractors, suppliers, and labour, and the client's commitment to project finance. The framework also shows that APS influences organisational and project performance indirectly and mediated by cash flow. Organisation and project performance are measured by evasion of price fluctuation, timely completion of the project, organisational efficiency, and improved profitability of organisations.

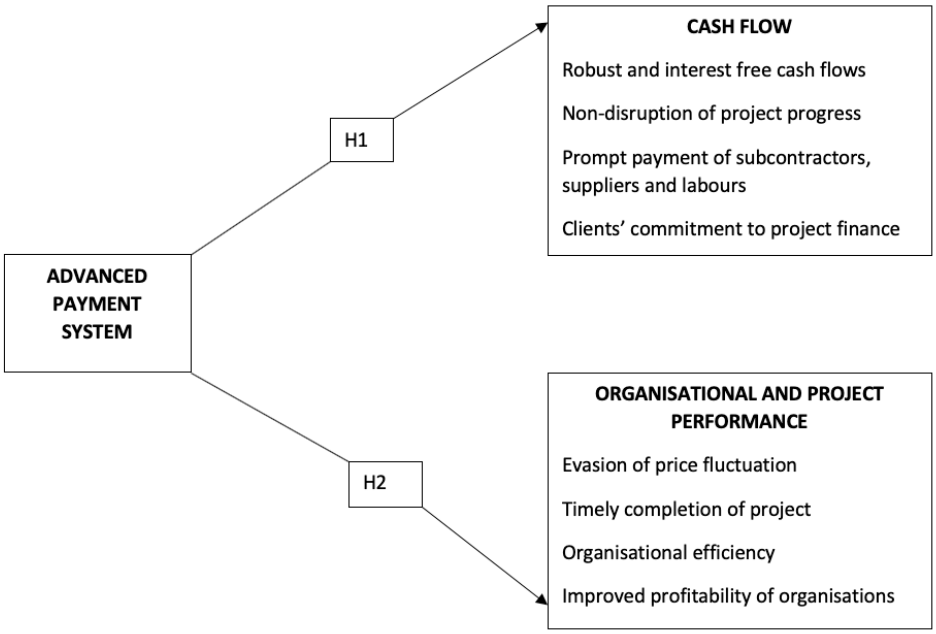


Figure 1: Framework of the effect of advance payment system (APS) on project cash flow and construction organisations and project performance

RESEARCH METHODS

The study is a part of an on-going PhD research. The study formulated a framework illustrating the domino effect of the advance payment system on project cash flow and organisation performance based on literature review. The effect and relationship between the advance payment system and project cash flow and organisation performance were evaluated using a structured questionnaire. The questionnaire was designed to elicit information, such as level of advance payment system used, project cash flow and organisation performance in use, from the respondents. Survey

Monkey was used to administer the questionnaires to respondents. The respondents were selected using a random sampling technique identifying every 2nd respondent on the sample frame. Therefore, each contractor listed on the Register of Contractors had an equal opportunity of being selected. The population for this study includes all 504 contractors listed in Grade 7 to 9 on the CIDB Register of Contractors in South Africa. The survey was sent to 50% of the population of contractors equating to a sample size of 252. As at April 24, 2019, 47 responses were received, which is a response rate of 18.65%. The analysis was based on the responses provided by 47 contractors.

The data collected from the respondents were analysed using percentage distribution, mean score, and t-test. Percentage distribution was used to analyse the extent of usage of the advanced payment system (APS). T-test for two independent means was used to determine the significance of the relationship between the advance payment system and organisation performance. The limitation of the study is that it is a preliminary study from an on-going PhD research. This will have an implication on the findings and conclusions of the study.

RESULTS AND DISCUSSION

Profile of respondents

The responses of 47 respondents from an ongoing PhD research work were used to validate the relationship identified in the framework. The analysis of the respondents' profile shows that 53.19% of the respondents have a bachelor's degree, 25.53% have a higher diploma, 12.77% have a certificate, and 8.51% have N4-6/NTC Certificate. For the designation of respondents, 70.21% of the respondents are in the director cadre, 25.53% are in the management cadre, and 6.38% indicated other designation. Only 29.05% of the respondents are Grade 7 contractors, 25.23% are Grade 8 contractors, while most of the respondents (45.72%) are Grade 9 contractors. For the class of work, 47.57% of the respondents are general building contractors, 47.43% of the respondents are civil engineering contractors, and 5.00% of the respondents are both general building and civil engineering contractors. The results show that the respondents have requisite formal knowledge, adequate to provide informed responses to the survey questions owing to their level of educational qualifications and experience. This was suitable for the research because it will enhance the validity or the dependability of data and subsequent findings.

Test of Hypothesis One

This sought to ascertain whether the advance payment system has a significant effect on project cash flows.

H1: The advance payment system has a significant effect on project cashflow.

An independent-samples t-test was conducted to test the significance of the effect of APS on project cash flow. The result shows that the effect of APS on project cash flow is not significant at $P<0.05$ [M1=1.55; M2=3.62; t-value= -0.033; p-value=0.488]. This result suggests that the respondents seldom make use of APS on their projects and this has resulted in its lack of significant impact on their cash flow. This finding contradicts the studies by Jaafari (1996) and Oke *et al.,* (2013), which indicated that APS effectively impacts project cash flow.

Table 1: T-value for the effect of Advance Payment System (APS) on project cash flow

Variables	Mean	T-Value	P-Value
Advance payment system	1.55	-0.033	0.488
Project cash flow	3.62		

Test of Hypothesis Two

This sought to ascertain whether the advance payment system has a significant effect on organisation and project performance.

H2: Advance payment system has a significant effect on organisation and project performance.

The result of the t-test shows that APS has no significant effect on organisation and project performance at $p< 0.05$ [M1=1.55; M2= 4.28; t-value=-0.0431; p-value= 0.484]. Specifically, the results indicated an occasional usage of APS among the respondents; hence organisation and project performance have not been impacted by APS. The finding of this study does not corroborate with the study of Ellis (1991), which reported that advance payment to contractors from the client is a catalyst for successful construction project delivery in a construction company.

Table 2: T-value for the effect of advance payment system (APS) on project and organisation performance

Variables	Mean	T-Value	P-Value
Advance payment system	1.55	-0.0431	0.484
Organisation and project performance	4.28		

DISCUSSION

The findings of this study indicated that APS has no effect on project cash flow and performance of organisations and projects. This contradicts the conclusions of studies such as Berends and Dhillon (2004), Aje *et al.,* (2017), Omopariola and Windapo (2018), and Oke *et al.,* (2013), which indicated that APS has a significant effect on organisation performance and cash flow of contractors. The result suggests that the use of APS among South African contractors is not widespread. This could be responsible for the non-significant effect of the APS on cash flow and organisation performance as found in this study. The domino effect of the use of APS on cash flow and organisation and project performance has been identified to include timely completion of project, non-disruption of project progress, improved profitability, and organisational efficiency (Li *et al.,* 2005; Motawa and Kaka, 2009; Spackman, 2002). Following this argument, the non-use of APS among the contractors could also have negative domino effects such as project delay, inefficiency of contractors, and project cost overrun (Rameezdeen *et al.,* 2006; Baloyi and Bekker, 2011). For example, Rameezdeen *et al.,* (2006) posit that non-availability of advance payment will make contractors' overdraft requirements tend to be much higher and turn the net cash flow to negative, thereby resulting in working capital deficiencies. The explanation from this is that working capital represents the liquid or near-liquid assets to lubricate the daily transactions of the project, and any discrepancy between current assets and current liabilities will affect the continuous flow of work on the construction site. Similarly, Oke *et al.,* (2013) concluded that non-availability of advance payment to contractors leads to delay in construction projects delivery, thereby increasing the total

cost of construction projects. Rameezdeen *et al.,* (2006) argued that this will result in contractors not being able to compete more effectively in the global market.

A study by Baloyi and Bekker (2011) on the causes of construction cost and time overruns of the 2010 FIFA World Cup stadiums in South Africa indicates the increase in the cost of material, inaccuracy of material estimates, and the shortage of skilled labour as the major causes of cost and time overrun. Given the positive domino effects of APS, the use of APS might have enabled the contractors to plan their budgets in advance and stabilise their cash flows, and, as a result, save time and cost on the projects (Schulz *et al.,* 2015).

CONCLUSION

This study examines the effect of APS on cash flow and organisation performance. The domino effect of APS on cash flow and performance of projects and organisations was explained in two parts. The first part indicated the effect of APS on cash flow, while the second part indicated the indirect effect of APS on the project and organisational performance mediated by cash flow. The effect was described as a domino effect in this study (see Figure 1). The validation of the domino effect of APS on cash flow and organisational and project performance, using the results from an ongoing PhD research, indicate that the effect of APS on project cash flow and organisation performance is not significant. The study concludes that the use of APS on projects is not widespread among the South African contractors, explaining why the effect of APS on cash flow and organisation was non-significant as against the conclusions of the past studies. This study linked the non-use of APS to cost and time overrun and poor performance of contractors in South Africa. However, the conclusions of this study must be interpreted with caution because the findings from this study were based on preliminary results from an on-going PhD research. The future direction for this ongoing PhD thesis will investigate whether there is a relationship between payment systems used on construction projects, financial management strategies and construction organisation and project performance.

ACKNOWLEDGEMENTS

The financial support of the University of Cape Town (UCT), the National Research Foundation (NRF) and TETFUND regarding this study are hereby acknowledged. The concepts articulated, and inferences arrived at, are those of the authors and are not really to be attributed to UCT, NRF or TETFUND.

REFERENCES

Abeysekera, V (2002) Reengineering payment procedures: An agenda for client financed construction *In:* S T Ng, S Cheung, K Lam and S Poon (Eds) *Re-Engineering Construction: Enabling and Motivating Excellence* Hong Kong: Professional Publication Ltd, , 79-85.

Aje, O I Olatunji, O A and Olalusi, O A (2017) Overrun causations under advance payment regimes, *Built Environment Project and Asset Management*, 7(**1**), 86 - 98.

Arditi, D Koksal, A and Kale, S (2000) Business failures in the construction industry, *Journal of Engineering, Construction and Architectural Management*, 7(**2**), 120-132.

Baloyi, L and Bekker, M (2011) *Causes of Construction Cost and Time Overruns: the 2010 FIFA World Cup Stadia in South Africa*. Available from https://www.ajol.info/index.php/actas/article/view/77173 [Accessed 24th May 2019]

Berends, T and Dhillon, J (2004) An analysis of contract cost phasing on engineering and construction projects, *The Engineering Economist*, 49(**4**), 327-337.

Choil, I and Kim, J (2014) An analysis of the characteristics of financial condition change of Korean construction companies: Using KMV model, *E3 Journal of Business Management and Economics*, 5(**1**),17-25.

Danuri, M M Munaaim, M C Rahman, H A and Hanid, M (2006) Late and non-payment issues in the Malaysian construction industry: Contractor's perspective *In: International Conference on Construction, Culture, Innovation and Management (CCIM)*, 26-29 November 2006, Dubai, United Arab Emirates**.**

Egan, J (1998) *Rethinking Construction*, London: DETR.

Ellis, C M (1991) Advance payment and project duration performance, *Australian Institute of Quantity Surveyors Journal*, 3(**2**),17-21.

Grosse-Ruyken, P T Wagner, S M and Jönke, R (2011) What is the right cash conversion cycle for your supply chain? *International Journal of Services and Operations Management*, 10, 13-24.

Hughes, W Gray, C and Murdoch, J (1994) Construction subcontracts: For what we are about to receive risk, management and procurement in construction, *In*: *7th Annual Construction Law Conference, Risk, Management and Procurement in Construction*, September 1994, Centre for Construction Law and Management, King's College London, 413-442.

Hwee, N G and Tiong, R L K (2002) Model on cashflow forecasting and risk analysis for contracting firms, *International Journal of Project Management*, 20(**1**), 351-363.

Jaafari, A (1996) Twining time and cost incentive-based contracts, *Management in Engineering*, 3(**7**),4-7.

Jagboro, G O (1998) The effect of payment for advance purchase of building materials on contractor's cash-flow projections, J*ournal of Financial Management of Property and Construction*, 3(**3**), 71-83.

Kenley, R (2003) *Financing Construction: Cash Flows and Cash Farming*. London: Routledge.

Li, B Akintoye, A Edwards, P J and Hardcastle, C (2005) Critical success factors for PPP/PFI projects in the UK construction industry, *Construction Management and Economics*, 23(**5**), 459-471.

Lip, E (2005) *Construction Payment Blues -Why That Domino Effect*? Davis Langdon and Seah Consultancy: Executive Summaries for the Practitioner, 3, 1-4.

Lowe, J G (1997) Insolvency in the UK construction industry, *Journal of Financial Management of Property and Construction*, 2(**1**), 83-107.

Lowe, J G and Moroke, E (2010) Insolvency in the UK construction sector. *In:* Egbu, C (Ed.), *Proceedings of the 26th Annual ARCOM Conference*, 6-8 September 2010, Leeds, UK. Association of Researchers in Construction Management, Vol. 1, 93–100.

Maravas, A and Pantouvakis, J P (2012) Project cash flow analysis in the presence of uncertainty in activity duration and cost, *International Journal of Project Management*, 30(**3**), 374-384.

Motawa, I and Kaka, A (2009) Modelling payment mechanisms for supply chain in construction. *Engineering Construction and Architectural Management*, 16(**4**), 325-336.

Mutti, C D N and Hughes, W (2002) Cash flow management in construction firms, *In:* Greenwood, D (Ed.), *Proceedings of the 18th Annual ARCOM Conference*, 2-4 September 2002, University of Northumbria, Association of Researchers in Construction Management, 23-32.

Nicholas, N (2005) *Late Payment Culture Creates Domino Effect.* Accountancy Agency, 30 June 2005 http://www.vnunet.com/articles/print/2139274 [Accessed 25th November 2018]

Odeyinka, H A and Kaka, A (2005) An evaluation of contractors' satisfaction with payment terms influencing construction cash flow, *Journal of Financial Management of Property and Construction*, 10(**3**), 171-180.

Odeyinka, H A Lowe, J and Kaka, A (2008) An evaluation of risk factors impacting construction cashflow forecast, J*ournal of Financial Management of Property and Construction*, 13(**1**), 5-17.

Oke, A E, Ogunsemi, D R, Aje, I O and Morakinyo, G A (2013) Performance of advance payment bond in construction projects, *In*: *1st NIQS Annual Research Conference*, 3-5 September, Shehu Musa Yar'Adua Centre, Abuja, Nigeria, 478-486.

Omopariola, E D and Windapo, A O (2018) Impact of payment systems on construction project and organization performance, *In*: *Proceedings of 42nd AUBEA Conference,* 26-28th September, Singapore, Australasian Universities Building Education Association (AUBEA).

Rameezdeen, R Palliyaguru, R S and Amaratunga, D (2006) Financing contractors in developing countries: impact of mobilisation advance payment, *In*: G Aouad, M Kagioglou, K Harris, H de Ridder, R Vrijhoef and C van den Broek (Eds), *3rd International SCRI Research Symposium*, Delft University, Conseil International du Bâtiment, Rotterdam, 153-165.

Schulz, F Schlereth, C Mazar, N and Skiera, B (2015) Advance payment systems: paying too much today and being satisfied tomorrow, *International Journal of Research in Marketing*, 32(**1**), 238-250.

Spackman, M (2002) Public-Private Partnerships: lessons from the British approach, *Economic Systems*, 26(**3**), 283-301.

Talagala, S J (1997) *Evaluation of Advance Payment Systems*, MSc dissertation, Department of Civil Engineering, University of Moratuwa, Katubedda.

Wang, G Dou, W Zhu, W and Zhou, N (2015) The effects of firm capabilities on external collaboration and performance: The moderating role of market turbulence, *Journal of Business Research*, 68, 1928-1936.

Withanachi, U T and Fernando, N G (2013) Overcoming sustainability issues through financial risk management in Private Financial Initiative projects. *In*: *The Second World Construction Symposium 2013, Socio-Economic Sustainability in Construction*, 14-15 June 2013, Colombo, Sri Lanka.

Wong, C Kaka, A P Fortune, C and Langford, D (2006) A multi-criteria decision-making framework for alternative payment systems using AHP analysis, *Journal of Construction Engineering Management*, 130(**5**), 691-698.

THE ATTRIBUTES OF SOCIAL SUSTAINABILITY IN CONSTRUCTION: A THEORETICAL EXPLORATION

Nurul Elma Kordi[1], Sheila Belayutham, Che Khairil Izam Che Ibrahim and Assrul Reedza Zulkifli

Construction Business and Project Management, Faculty of Civil Engineering, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia

Sustainability in construction is a process of compliance to the three main pillars of sustainability, which are environmental, economy and social practices that influences project performance. Most of the previous studies have focused on the dimensions of environment and economy due to the clearly expressed quantitative indicators, as compared to the social dimension, which is more subjective in nature. Therefore, there is a lack of understanding on what Social Sustainability (SS) actually means, since there are different perceptions and motivations on SS by different stakeholders, at different phases of the construction project life cycle. Additionally, the strong focus of past SS studies on the construction stage of project has left other phases to be side-lined. Therefore, this is would be one of the few studies that considers the attributes of SS for the entire construction project life cycle. The objectives of this paper are to identify the attributes of SS in construction, and to relate the social attributes to the different phases in construction project life cycle. This paper has conducted meticulous systematic review, with 45 studies that have been critically assessed on SS in construction. The articles have been analysed with a particular focus on the definition of SS, research methods used, the central themes covered and the evolution of the debate including theories and the main findings. Finally, the outcome of this study would be an integrated framework that displays the relationship between SS attributes with the different phases in construction project life cycle. The framework would benefit all construction stakeholders towards understanding the attributes of SS that may further influence their decision making on the social aspects of their projects.

Keywords: Attributes, social sustainability, systematic review

INTRODUCTION

Sustainable construction has been recognized as a main priority by most countries. Sustainability in construction is a process of compliance to the three main pillars of sustainability, which are environmental, economy and social practices that influences project performance. As a regional society, the community is a place of people's social life belonging in a certain geographical area. As a social space to meet the needs of residents, it is also a place for community capacity building. Thus, to realize the healthy and orderly development of a city, the initial step is to conduct community sustainable construction. Achieving sustainability is becoming increasingly critical for measuring the overall success of projects. Given the complexity of construction projects, the successful management of sustainability related targets requires joint

[1] elma8207@salam.uitm.edu.my

Kordi, N E, Belayutham, S, Ibrahim, C K I C and Zulkifli, A R (2019) The Attributes of Social Sustainability in Construction: A Theoretical Exploration *In:* Gorse, C and Neilson, C J (Eds) *Proceedings of the 35th Annual ARCOM Conference,* 2-4 September 2019, Leeds, UK, Association of Researchers in Construction Management, 629-638.

efforts from the major stakeholders involved, including project clients, contractors, suppliers, and the general public.

The economy and the environmental issues in regard to construction activities have been the household term and have always been the focus of community development. However, with the improvement in living standards, people's requirements for residential areas have been continuously improving, as non-materialistic lifestyle may also improve well-being to some extent. Therefore, from the social perspective, social sustainability (SS) is an important part of urban sustainable development. However, developers often provide little attention, with minimal holistic exploration on the aspects of SS since it does not have direct impact on them (Bamgbade, Kamaruddeen, and Nawi, 2017; Sierra, Yepes, García-Segura, and Pellicer, 2018; Sierra, Yepes, and Pellicer, 2017). While significant literature is available on economic and environmental impacts; little has been done to investigate the social attributes and social impacts of construction projects. Furthermore, decisions on economic and environmental impacts have been easier to be determined, as compared to social impacts, where difficulties were encountered in formulating measurable SS criteria (Nakamba, Chan, and Sharmina, 2017). The developers have practiced SS in their housing development, but the understanding and application differs for each project. This situation causes confusion among stakeholders due to the non-standardization of the elements. This is partly due to the lack of consensus on SS indicators and their relative importance in different projects. SS directly relates to how people are affected by a project and therefore, may be perceived as a highly subjective concept. However, excluding the social dimension in an infrastructure development will have detrimental effect in short- and long-term period that determines results of the entire project life cycle.

Therefore, this study attempts to identify the attributes of SS and to relate the social attributes to different phases of construction project life cycle. This study has been conducted through systematic review and is guided by the following research questions; i) RQ1: What are the social sustainability attributes found in construction practices? ii) RQ2: How does the attributes of social sustainability relate to construction project life cycle? In order to address these questions, this study has identified the SS attributes in construction and further designated the SS attributes over the project life cycle in construction.

METHODOLOGY

The study has adopted a secondary study from systematic review of published literatures on social sustainability (SS) in construction or project. This method seeks to explore the attributes of SS in construction, due to the limited past studies found on this subject. The gap in knowledge would require a proper background study in order to appropriately position new research activities in regard to SS in construction. Systematic review (SR) is an important scientific research approach in identifying, evaluating, interpreting and summarising all available research on a subject matter. SR allows researchers to examine the strength of the published evidences and has been argued to be one of the most efficient method for identifying and evaluating literatures. The general workflow of the SR process is illustrated in Figure 1.

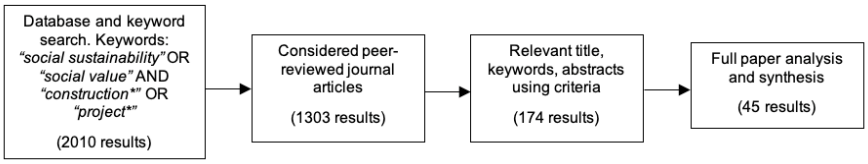


Figure 1: Systematic review process

Systematic review (SR)

Gupta *et al.,* (2018) have suggested a-five step process of conducting SR, which are: (i) development of research questions (ii) identification of relevant published studies (iii) evaluation of related and quality studies (iv) summarization of evidence; and (v) interpretation of the findings.

In this study, the first step was the formulation of research questions to guide the review. This was followed by literature search in the Scopus database in order to identify articles to be included in the review. Scopus database was chosen because it is the most effective search engine with the largest online database of peer-reviewed publications. The search results can also be sorted by number of citations, as compared to google scholar, ScienceDirect and PubMed, as explained by Tober (2011). The common practice in SR studies is to limit the findings to peer-reviewed articles published in English, due to language communality. The findings were also not confined to any year ranges.

In carrying out searches for the articles in Scopus, the keywords of "social sustainability" OR "social value" AND "construction*" OR "project*" were used to identify materials in their titles, abstracts, or keywords. The asterisk ("*") was used at the end of the search keyword to cover a broad range of results. From the search conducted between 1st December 2018 to 5th January 2019, in total, 2010 hits have resulted from the initial search that contained any one instance of the phrase "social sustainability" or "construction*" or "project*". These results consist of various sources such as research articles, conference proceedings, books and trade publications. However, as the focus of this review was on peer-reviewed journal articles, all other sources were omitted from the search. A total of 1303 peer-reviewed journal articles were found in the second step of review ("identification of relevant published studies") that were potential to be included in this review.

Since the review is focused on SS in construction/project, there was a need to select only the related content. Therefore, from the earlier results (1303), the search process was done again with the keyword "social sustainability in construction". As a result, 174 articles that contains the keywords "social sustainability in construction" AND "social sustainability in project" were found within the results of 1303 peer-reviewed journal articles.

The third step of the review ("evaluation of the related and quality studies") involves screening and sorting of the identified articles, which involved actual reading of the articles' abstracts in order to ensure the relevance with the research questions. This review has adopted several inclusion and exclusion criteria to narrow down the selection of literatures. The decisions regarding inclusion and exclusion remains relatively subjective and should be made by more than one reviewer. Therefore, four authors of this paper have examined the titles, keywords, abstracts and overall contents of the 174 articles. The articles with title and abstract beyond the scope of the review were removed. After the full texts were checked and reviewed by the authors, with the aim of identifying the attributes of SS for the entire construction

project life cycle, a final count of 45 articles published in 24 journals were selected as the findings from the SR. The 45 articles have been selected based on the emphasis on SS in construction or project.

A frequency analysis has been conducted to analyse the articles according to the distribution of papers across journals, time of publication and research methods. In line with the two research questions (RQ1 and RQ2) set out in this study, a qualitative analysis of the papers has been done, focusing on the following areas; i) definitions of SS in construction / project; ii) main topics/themes; and iii) the evolution of debate including research setting, theoretical frameworks and major findings. This study has adopted manual data extraction for the content analysis, as this study does not involve large set of data and hence, does not necessitate the use of computer assisted qualitative data analysis software. In addition, manual coding enables familiarization with the data, subsequently allows critical processes of analyses and interpretation by the researchers (Basit, 2003).

RESULTS AND FINDINGS

Frequency analysis

The frequency analysis provides descriptive results of the 45 articles that were related to SS in construction / project. Table 1 provides the overview on the sources of publication across different journals. This result shows that the highest number of SS in construction was found in three journals: 1) Sustainability Switzerland; 2) Journal of Construction Engineering and Management; and 3) Journal of Cleaner Production and can be regarded as core journals in the field. The top three journals contributed to 42.2 per cent of total publications with 19 of the 45 papers. The next four journals (Number 4 to 7) produced 9 of 45 papers (20 per cent). The remaining 17 journals with the least number of papers (with one paper each) contributed 17 of 45 papers (37.8 per cent).

It was also found that 77.8% of the materials were published between 2015 and 2019 from top three countries, namely, the United States (9 articles), China (9 articles), and Australia (7 articles). The three leading authors in this field were found to be Pellicer, E. (6 articles), Sierra, L.A. (4 articles) and Yepes, V (4 articles). SS has received attention, mainly in the field of construction projects, operations management and risks.

The spread of papers across the years has shown a growing trend in the articles published since 2012, with steeper increase occurring from year 2014 onwards. The distribution of publications can be divided into three sub-periods. During the first sub-period year (2012 to 2014), 10 articles were found; 15 articles were published in the second sub-period year (2015 to 2017); and in the third sub-period year (2018 to 2019), 20 articles were found. However, only 8 articles were found in year 2019 (on SS in construction), as the search for this SR was done in December 2018 to early January 2019.

Research methods applied in the reviewed papers

The consideration on methodological approaches also enables further examination of the articles. Table 2 summarises the research methods used in the reviewed papers. The research methods applied in relation to SS in construction extended from empirical papers to literature reviews, as well as conceptual and theoretical papers. Importantly, not all papers have focused on one method, as they have covered both qualitative research methods and mathematical modelling tools. In such cases, these

papers are considered as utilising mixed-method approach. As Table 2 shows, papers based on literature review and case study covers almost half of the articles reviewed (44.6%).

Table 1: Distribution of articles per journal

No	Name of journal	Frequency
1	Sustainability Switzerland	7
2	Journal of Construction Engineering and Management	6
3	Journal of Cleaner Production	6
4	Journal of Management in Engineering	3
5	Journal of Architectural Engineering	2
6	Journal of Urban Planning and Development	2
7	Facilities	2
8	17 journals (with 1 relevant paper each)	17
	Total	45

There has been a rapid increase in literature review papers and a gradual rise in the number of empirical research papers that uses qualitative (e.g. case studies and interviews) and quantitative (e.g. surveys) methods. In line with a field that is emerging in importance, the number of papers seeking to develop theory has also grown (13.3%). In terms of empirical studies, case study research, surveys and interviews contribute over 50 per cent of the reviewed papers. Experiments and mathematical modelling were found in 4.4 per cent of the articles.

Table 2: Distribution of research methods in the reviewed papers

Research interval	2012 – 2014	2015 – 2017	2018 - 2019	Total no. of papers	Percentage (%)
Literature review	4	1	3	8	17.8
Case study	1	8	3	12	26.8
Survey	1	2	3	6	13.3
Theory/concept	1	2	3	6	13.3
Mathematical modelling	0	0	1	1	2.2
Interviews	2	1	3	6	13.3
Mixed methods	0	1	4	5	11.1
Experiment	1	0	0	1	2.2

Social Sustainability in Construction

While scholars studying project life cycle in construction have shown an increasing interest in researching social issues, only few studies have properly defined social sustainability (SS), which have been defined from a number of perspectives, as shown in Table 3. Generally, SS in construction is defined as key parameters or series of processes to improve the health, safety, and well-being of the current and future generations. These definitions point to the idea that SS is related to the management of practices, capabilities, stakeholders and resources to address human potential and welfare, both within and outside the communities of construction.

The underlying question about what the social goals for SS are, can be used as a starting point when aiming to approach SS. SS must be understood in its context and be reinterpreted due to occasion. Olsson, Galaz, and Boonstra (2014) argued that SS

is not something that can be translated into a sentence but should be seen as a conception that provides direction.

Table 3: Exemplary definitions of social sustainability in construction

No	Authors	Definition
1	(Olakitan Atanda, 2019)	"as an aspect that contributes to the enlightening and sustaining the human welfare"
2	(Doloi, 2018)	"function of set of key parameters such as interest, impacts, understanding, and satisfaction perceived by the wider community on various project issues"
3	(Valdes-Vasquez & Klotz, 2013)	"a series of processes for improving the health, safety, and well-being of current and future generations"
4	(Toole & Carpenter, 2013)	"policies and institutions that have the overall effect of integrating diverse groups and cultural practices in a just and equitable fashion"
5	(Almahmoud & Doloi, 2015)	"measure of ability of people work together for common purposes in groups and organizations"

Doloi (2018) confirms the non-existence of general or determined definition of SS, as it is viewed as dynamic, dependent on situation and could change over time. However, Olsson *et al.,* (2014) expresses a general content as an endeavour to mount the concept of SS.

Social Sustainability Framework

The literature on social sustainability (SS) that refers to construction projects emphasizes that stakeholder consideration is one of the most important social criteria that should be considered. However, one of the limitations observed in the current debate on SS in construction is the heavy focus on the construction stage of project, because of the newly emerging social procurement policy (Raiden, Loosemore, King, and Gorse, 2019). One way to evaluate SS in construction projects is to identify and measure the SS criteria. The following research studies have tried to identify the SS criteria in construction projects.

Sierra *et al.,* (2016) identified 36 SS criteria assessed at each stage of the Chilean public infrastructure project life cycle, using a series of three-round Delphi method with 24 Chilean experts. They concluded that the most relevant criteria, considering life cycle stages, were stakeholder participation (design and demolition stages), external local population (design stage), internal human resources (construction and demolition stages), macrosocial action of socioenvironmental activities (construction stage), and macrosocial action of socioeconomic activities (operation stage). Table 4 shows the SS attributes collected from the systematic review (SR).

From the SR, there were overlapping SS attributes between the different authors. Therefore, the overlapping attributes with similar meanings have been synced into a representative attribute. Figure 2 has been established to portray the influence of SS attributes over the project life cycle in construction. It is worth highlighting that not all stages in the construction project life cycle contribute equally to the attributes of SS. In fact, it was found that activities conducted during the planning stage significantly affects most of the criteria for Stakeholder Engagement, which is consistent with Sierra *et al.,* (2016) and Valdes-Vasquez and Klotz (2013).

Expectations of the owner, designer, and public at the initial phase of a project is important in order to get the desired output from construction. Therefore, the involvement of buyers and surrounding communities is crucial. The needs and

requirements of the community should be at the core of planning for construction projects and should not be compromised (Almahmoud and Doloi, 2015).

Table 4: Social sustainability attributes

No	Types of project	Social sustainability attributes	Example of references
1.	Building / housing	Life cycle assessment, stakeholder-based assessment, society, worker, occupants, local community, cultural value, satisfaction, safety and health labour practices, human rights, indoor climate, accessibility to living opportunities, depreciation rate, working hours, community education, building quality, socioeconomic growth	(Lang & Yang, 2019; Liu & Qian, 2019; Stender & Walter, 2019; Surbeck & Hilger, 2014; Wang, Zhang, & Lu, 2018)
2.	Construction (general)	Cultural heritage, employment, health and safety, training, effects on users, comfort, professional ethics, accessibility, usability, aesthetic degradation, responding to the needs of specific groups, improved quality of daily life, effective public participation, social flexibility, government support and market orientation, company age, staff strength, human rights, regulation.	(Almahmoud & Doloi, 2015; Bamgbade et al., 2017; Montalbán-Domingo et al., 2019; Valdes-Vasquez & Klotz, 2013)
3.	Infrastructure projects (Road, highway, railway)	Stakeholder engagement, impact, communication, satisfaction network, liveability health & comfort, social justice, public opinion, fair and equitable, respecting human safety, security and health, cultural heritage.	(Doloi, 2012, 2018; Sierra et al., 2017)
4.	Other projects (Renewal Projects, Offshore wind power farms, Sanitation Organizations)	Stakeholder engagement, sense of community, cultural heritage, health and safety, local preference / social value, professional ethics, public participation training, social capital, emotion experience, life satisfaction, cleanliness, convenience, financial contribution, pollution, modernity knowledge, costs.	(Montalbán-Domingo et al., 2019; Toole & Carpenter, 2013; Yildiz et al., 2019; Zou et al., 2018)

At the initiation phase, the project objectives are identified and therefore, requires employment and stakeholder engagement. A feasibility study is conducted to investigate whether each of the delivering option addresses project objectives and a final recommended solution would be determined. The major deliverables and participating work groups are identified, and the project team begins to take shape.

The next phase is the planning phase, where the project's solution is further developed and the necessary steps to meet the project's objectives are planned. Once the project team has identified the work, prepared the schedule, and estimated the costs, the three fundamental components of the planning processes are complete (user consideration). During the third phase, the execution phase, the project plan is in motion and work is performed (team formation). It is important to maintain control and communicate as needed during implementation. During the final closure phase, the emphasis is on releasing the final deliverables to the customer, handing over project documentation to the business, terminating supplier contracts, releasing project resources, and communicating the closure to all stakeholders (macro social performance).

CONCLUSIONS

This article contributes to the current gap in knowledge by identifying the SS attributes and categorizing the attributes based on the type of project; namely, building/housing, construction, infrastructure project and others. Subsequently, the attributes of SS were mapped along with the project life cycle in construction. Findings from the SR suggest numbers of redundant attributes or terms with similar meanings, which might cause confusion. This study has contributed in categorising

the SS attributes with similar or closely related elements to improve the understanding on SS itself, as well as a guidance for decision making among industry stakeholders.

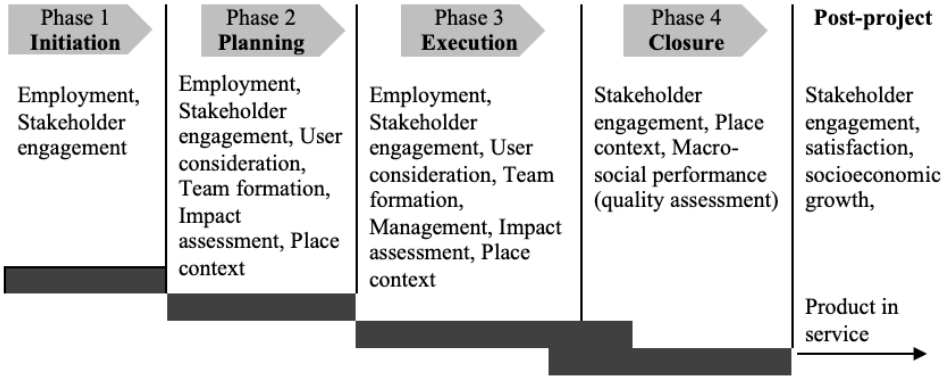


Figure 2: The framework of social sustainability attributes over construction project life cycle

The implication of this study aligns well with the movement towards adopting/ adapting the concept of SS in construction projects, by providing guidance in addressing SS principles at every stage of a project life cycle. It is worth highlighting that Stakeholder Engagement is a major SS attribute that plays a critical role in the practice of social sustainability across construction project lifecycle.

For the industry practitioner, this SS framework serves as an important scaffold for future discussion among organizations and institutions that aim to assess a truly sustainable construction project. The findings of this study may also help decision makers to achieve organizational core values, such as caring for employees and improving community relations. However, policies should be implemented to promote the use of social criteria and metrics in the award of projects and in the evaluation and monitoring of social performance in the construction industry.

REFERENCES

Almahmoud, E and Doloi, H K (2015) Assessment of social sustainability in construction projects using social network analysis, *Facilities*, 33(**3-4**), 152-176 https://doi.org/10.1108/F-05-2013-0042.

Bamgbade, J A, Kamaruddeen, A M and Nawi, M N M (2017) Malaysian construction firms' social sustainability via organizational innovativeness and government support: The mediating role of market culture, *Journal of Cleaner Production*, 154, 114-124.

Basit, T N (2003) Manual or electronic? The role of coding in qualitative data analysis, *Educational Research*, 45(**2**), 143-154.

Chang, R D, Zuo, J, Soebarto, V, Zhao, Z Y and Zillante, G (2017) Dynamic interactions between sustainability and competitiveness in construction firms: A transition perspective, *Engineering, Construction and Architectural Management*, 24(**5**), 842-859.

De Lozano, L R, Dueñas-Osorio, L and Padgett, J E (2014) The social sustainability index for small infrastructure projects: A proposition, *International Journal of Sustainability in Economic, Social and Cultural Context*, 11(**1**), 25-38.

Doloi, H (2012) Assessing stakeholders' influence on social performance of infrastructure projects, *Facilities*, 30(**11/12**),531-550.

Doloi, H (2018) Community-centric model for evaluating social value in projects, *Journal of Construction Engineering and Management*, 144(**5**), 04018019.

Gupta, S, Rajiah, P, Middlebrooks, E H, Baruah, D, Carter, B W, Burton, K R and Miller, M

M (2018) Systematic review of the literature: Best practices. *Academic Radiology,* 25(**11**), 1481-1490.

Ilhan, B and Yobas, B (2019) Measuring construction for social, economic and environmental assessment, *Engineering, Construction and Architectural Management*, 26(**5**), 746-765.

Lang, Y and Yang, Q (2019) Does public infrastructure breed consumption downgrade and overcapacity in China? A DSGE approach on macroeconomic effects, *Sustainability (Switzerland)*, 11(**3**).

Liu, S and Qian, S (2019) Evaluation of social life-cycle performance of buildings: Theoretical framework and impact assessment approach, *Journal of Cleaner Production*, 213, 792-807.

Montalbán-Domingo, L, García-Segura, T, Sanz, ; M Amalia, Pellicer, E and Asce, M (2019) Social sustainability in delivery and procurement of public construction contracts, *Journal of Management in Engineering*, 35(**2**), 1-11.

Nakamba, C C, Chan, P W and Sharmina, M (2017) How does social sustainability feature in studies of supply chain management? A review and research agenda, *Supply Chain Management*, 22(**6**), 522-541.

Olakitan Atanda, J (2019) Developing a social sustainability assessment framework, *Sustainable Cities and Society*, 44(May 2018), 237-252.

Olsson, P, Galaz, V and Boonstra, W J (2014) Sustainability transformations: A resilience perspective, *Ecology and Society*, **19**(4).

Raiden, A, Loosemore, M, King, A and Gorse, C (2019) *Social Value in Constrcution 1st Edition*. Abingdon, UK: Routledge.

Sierra, L A, Pellicer, E and Yepes, V (2016) Social sustainability in the lifecycle of chilean public infrastructure, *Journal of Construction Engineering and Management*, 142(**5**), 05015020.

Sierra, L A, Yepes, V, García-Segura, T and Pellicer, E (2018) Bayesian network method for decision-making about the social sustainability of infrastructure projects, *Journal of Cleaner Production*, 176, 521-534.

Sierra, L A, Yepes, V and Pellicer, E (2017) Assessing the social sustainability contribution of an infrastructure project under conditions of uncertainty, *Environmental Impact Assessment Review*, 67(June) 61-72.

Stender, M and Walter, A (2019) The role of social sustainability in building assessment, *Building Research and Information*, 47(**5**), 598-610.

Surbeck, C Q and Hilger, H (2014) Social sustainability and important indicators in infrastructure. *In*: *World Environmental and Water Resources Congress 2014*, June 1-5, Portland, Oregon, 2078-2093.

Tober, M (2011) PubMed, ScienceDirect, Scopus or Google Scholar - Which is the best search engine for an effective literature research in laser medicine? *Medical Laser Application*, 26(**3**), 139-144.

Toole, T M and Carpenter, G (2013) Prevention through design as a path toward social sustainability, *Journal of Architectural Engineering*, 19(**3**), 168-173.

Valdes-Vasquez, R and Klotz, L E (2013) Social sustainability considerations during planning and design: Framework of processes for construction projects, *Journal of Construction Engineering and Management*, 139(**1**), 80-89.

Wang, H, Zhang, X and Lu, W (2018) Improving social sustainability in construction : Conceptual framework based on social network analysis, *Journal of Management in Engineering*, 34(**6**), 1-9.

Yildiz, S, Kivrak, S and Arslan, G (2019) Contribution of built environment design elements to the sustainability of urban renewal projects: Model proposal, *Journal of Urban Planning and Development*, 145(**1**).

Zou, T, Su, Y and Wang, Y (2018) Examining relationships between social capital, emotion experience and life satisfaction for sustainable community, Sustainability (Switzerland) 10(**8**), 2651.

CONTROL MODES AND INTENSITY IN DESIGN CONSULTING PROJECTS: PROFESSIONALS AS AGENTS

Yadi Li[1], Yan Ning[2], Steve Rowlinson[3] and Derek Asante Abankwa[4]

[1,3&4] *Department of Real Estate and Construction, Knowles Building, The University of Hong Kong, Pokfulam Road, Hong Kong*

[2] *Department of Construction and Real Estate, Southeast University, Nanjing City, Jiangsu Province, China*

Control as a primary project governance mechanism and a basic managerial function has been extensively utilized in projects which embrace principal-agent relationships. Prior studies have shown that control is an effective strategy in mainstream principal-agent relationships for principals to motivate their agents to behave in a desired manner and deliver satisfactory outputs. However, little is known about how principals perform control when agents are professionals providing intangible services in professional service projects. Therefore, this study aims to address the research question of how clients determine control strategies (including control modes and intensity) in design consulting projects. The specific research objective is to develop a conceptual framework for determining control modes and intensity in design consulting projects. Based on literature review and agency theory, this conceptual paper establishes a framework comprising antecedents of control modes and control intensity which indicate the feasibility and necessity of control respectively. This study enriches the knowledge about how to determine control strategies in professional service projects. Also, it expands the application of agency theory by delineating a particular type of principal-agent relationship of which agents are professionals.

Keywords: client-professional relationship, control mode, control intensity

INTRODUCTION

The control strategy is extensively adopted by project clients to motivate their agents to behave in a desired manner and deliver satisfactory outputs (Choudhury and Sabherwal, 2003). Control has shown its effectiveness in improving performances of various projects with observable processes and tangible outputs, such as construction projects (Tuuli, Rowlinson, and Koh, 2010), dwelling fit-out projects (Ning, 2017a, 2017b), and information systems development (ISD) projects (Kirsch, 1997).

Design consulting projects, however, are distinctive in tasks characteristics and professional agents. On the one hand, the design work is notoriously hard to supervise and evaluate (Ballard, 1998). As a professional service, it has knowledge-intensive tasks (Von Nordenflycht, 2010), intangible and creative services (Winch and Schneider, 1993), iterative processes (McGeorge, 1988), customized outputs

[1] liyadi@connect.hku.hk

Li, Y, Ning, Y, Rowlinson, S and Abankwa, D A (2019) Control Modes and Intensity in Design Consulting Projects: Professionals as Agents *In:* Gorse, C and Neilson, C J (Eds) *Proceedings of the 35th Annual ARCOM Conference,* 2-4 September 2019, Leeds, UK, Association of Researchers in Construction Management, 639-648.

(Greenwood, Li, Prakash, and Deephouse, 2005), and co-production between clients and designers (Homburg and Stebel, 2009). On the other hand, designers may be reluctant to be restrained (Emmitt, 2014) since they are professionals who have esoteric design expertise, distinctive ethics, and a great deal of autonomy (Sharma, 1997). Notwithstanding such distinct characteristics of the design consulting project, few studies differentiate it from ordinary tangible projects and examine control strategies in design consulting projects. It is unknown how clients select and conduct control strategies over designers in design consulting projects.

Therefore, this study tends to address the research question of how clients determine control strategies (including control modes and control intensity) in design consulting projects. The specific research objective is to develop a conceptual framework for determining control modes and intensity in design consulting projects. The framework is established based on the literature review and agency theory. It embraces control modes and intensity determined by the feasibility and necessity of control respectively. This conceptual paper enriches the knowledge about how to determine control strategies in professional service projects.

The remainder of this study is structured as follows. Section two presents the literature review. This is followed by the theoretical background—agency theory. The fourth section outlines the development of the framework for determining control modes and intensity in design consulting projects. The final section presents the conclusions, contributions, limitations, and directions for future research.

LITERATURE REVIEW

Control is defined as "attempts by one individual or organization to motivate another to act in a manner consistent with specific expectations and objectives" (Rustagi, King, and Kirsch, 2008: 126). It is a dyadic concept involving two parties - the "controller" who performs control strategies, and the "controllee" who is the receiver of control (Kirsch and Choudhury, 2010; Wiener, Mähring, Remus, and Saunders, 2016). This study focuses on the control strategy adopted by the client (controller) over the designer (controllee) in design consulting projects.

The controller commonly adopts two types of control: formal and informal control (Dekker, 2004; Jaworski, 1988). Formal control uses written prescriptions (e.g. policies, contracts, and procedures) to predefine and evaluate the controllee's behaviour and outcomes (Das and Teng, 2001). It consists of behaviour and outcome control modes (Ouchi, 1977; Ouchi and Maguire, 1975). The former usually prescribes, monitors, and evaluates the controllee's behaviour, and the latter aims to make sure the interim and final outcomes meet the controller's requirements (Kirsch, 1996; Wiener *et al.,* 2016). Informal control relies on social or people strategies, including clan and self-control modes (Kirsch, 1997). Clan control develops shared values and norms among group members to motivate the desired behaviour (Kirsch, Ko, and Haney, 2010; Wiener *et al.,* 2016), whereas self-control depends on the controllee's self-regulation and self-monitoring (Tuuli *et al.,* 2010).

A central theme of control-related studies is how the controller selects control modes, and a series of antecedents of control has been identified (Wiener *et al.,* 2016). Much of the work on the antecedents of control modes is primarily based on Ouchi's (1977, 1979) seminal framework and Eisenhardt's (1985) research. Two antecedents of control modes in Ouchi's framework are the controller's knowledge of transformation processes and outcome measurability (Ouchi, 1977, 1979). As Kirsch and Choudhury

(2010) summarized, high level of outcome measurability and the controller's knowledge of transformation processes recommend the use of outcome control and behaviour control respectively; otherwise, clan control is preferred (Kirsch and Choudhury, 2010; Ouchi, 1977, 1979). Eisenhardt (1985) extends Ouchi's framework by adding behaviour observability as an antecedent. Behaviour control is appropriate when the controllee's behaviour is observable (Eisenhardt, 1985). Ouchi's (1977, 1979) and Eisenhardt's (1985) work laid a foundation for later related studies of which a considerable portion stick to these three antecedents of control modes (e.g. Choudhury and Sabherwal, 2003; Das and Teng, 2001; Kirsch, 1996, 1997).

In much of the extant literature, antecedents of control primarily focus on the feasibility of performing a specific control mode from the controller's perspective (Kirsch and Choudhury, 2010). For example, the controller's knowledge of transformation process and ability to observe the controllee's behaviour indicate the feasibility of behaviour control, and the feasibility of outcome control depends on the outcome measurability (Eisenhardt, 1985; Ouchi, 1977, 1979). However, the need for control in a given context has not been taken into full consideration (Kirsch and Choudhury, 2010). Prior studies neglect the varying level of necessity of control, and blindly assume control is needed at the same level in any contexts.

The varying needs for control, however, may require that control strategies should be performed at different degrees in different contexts. Control intensity is introduced to indicate the extent to which the controller exercises a specific control mode (Remus and Wiener, 2012). Prior studies merely focus on the selection of types of control modes, with only a few of them considering what determines the degree of control (e.g. Gregory, Beck, and Keil, 2013; Remus and Wiener, 2012; Rustagi *et al.,* 2008).

To fill in these research gaps, this study develops a conceptual framework in which feasibility and necessity of control are considered as antecedents of control modes and intensity respectively. It supplements existing literature by incorporating the necessity of control and control intensity into the selection of control strategy.

THEORETICAL BACKGROUND

Agency theory is adopted as the theoretical background for two main reasons. First, its core of principal-agent relationship reveals the nature of client-designer relationships in design consulting projects where clients (principals) hire designers (agents) to develop a design solution and achieve their goals (Gray and Hughes, 2001; Macmillan, 2004). As suggested by Kirsch and Choudhury (2010), the nature of controller-controllee relationships can predict the necessity of control in given contexts. Thus, the nature of client-designer relationships based on agency theory would reflect the necessity of control and further determines the control intensity under specific circumstances. Second, agency theory has been widely used in control-related studies, examining the feasibility of control modes. A large percentage of existing antecedents of control modes are derived from agency theory (e.g. Eisenhardt, 1985, 1989).

There are two basic assumptions of agency theory. Based on the economic man model, agency theory assumes that principals and agents are rational actors seeking to maximize self-interests (Bergen *et al.,* 1992). Agents hope to obtain the highest reward for the least amount of workload, whereas principals prefer the biggest gain with the lowest cost (Quinn, 2011). Hence, the first assumption of agency theory is the goal conflict between principals and agents (Anderson and Oliver, 1987; Davis,

Schoorman, and Donaldson, 1997). Although agents are hired by principals, they may prefer to pursue self-interests rather than act in the best interests of principals (Mahaney and Lederer, 2003). To increase the opportunities for pursuing their interests, agents would like to grasp more information and be reluctant to share with principals (Van Slyke, 2006). This phenomenon of the agents' privately-held information is the second assumption of agency theory, called information asymmetry (Waterman and Meier, 1998).

Two typical agency problems may arise from goal conflict and information asymmetry between principals and agents: Adverse selection (hidden information) referring to the situations in which the potential agents exaggerate their qualification to obtain the job (Quinn, 2011); and moral hazard (hidden actions) which is the agent's shirking and opportunistic behaviour (Eisenhardt, 1989; Ferris, 1992). The former happens typically in the pre-contractual phase, whereas the latter is a kind of post-contractual problems (Schneider, 2007). This study mainly focuses on moral hazard problems in design consulting projects.

Control is advocated by agency theorists to curb moral hazard problems (Davis *et al.,* 1997; Toivonen and Toivonen, 2014). It provides principals a tool to regulate or adjust agents' activities to ensure that agents behave in a manner consistent with the principals' goals (Bergen *et al.,* 1992; Schneider, 2007). Davis *et al.,* (1997) argue that the management philosophy of agency theory is control-oriented. Control relationship between the principal and the agent is inherent in the agency model (Schillemans, 2013).

Therefore, agency theory explains why principals perform control over agents. It provides a theoretical background to understand the nature of client-designer relationships and reflect the necessity and feasibility of control in design consulting projects.

Development of the Conceptual Framework

Based on the literature review and agency theory, this study develops a conceptual framework to guide clients on how to determine control strategies in a given context. It is an integrated framework in which both feasibility and necessity of control are considered as antecedents, and control strategies consist of both control modes and intensity.

Structure of the Conceptual Framework

The conceptual framework (Figure 1) has two main parts: control modes and control intensity.

Control modes

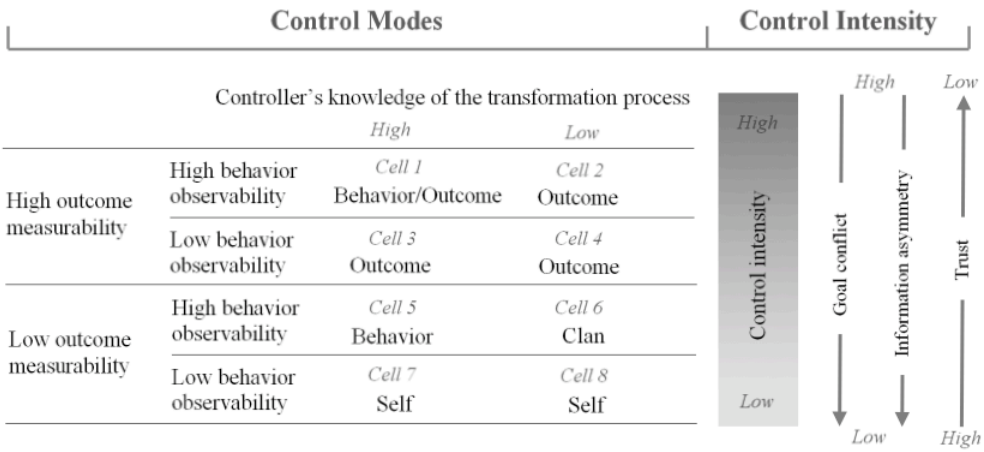
The selection of control modes has been extensively studied. The antecedents of control modes are derived from Ouchi's (1977, 1979) and Eisenhardt's (1985) studies, including outcome measurability, behaviour observability, and the controller's knowledge of the transformation process. The sub-framework of control modes is adapted from models proposed by Govindarajan and Fisher (1990) and Kirsch (1996). Specifically, outcome control is feasible when the outcome measurability is high (cell 1-4), whereas behaviour control is utilized provided that both behaviour observability and clients' knowledge of the transformation process are high (cell 1,5). The use of clan control will increase when behaviour observability is high but the other two factors are low (cell 6). When both outcome measurability and behavior observability are low, it is better to rely on the designers' self-control (cell 7,8).

Control intensity

The framework for control strategy selection is expanded by incorporating the necessity of control as antecedents of control intensity. As Kirsch and Choudhury (2010) suggested, the necessity of control depends on the nature of the controller-controllee relationships. This study adopts agency theory to understand the relationship between clients and designers. Three dimensions of client-designer relationships are introduced to indicate the necessity of control, including goal conflict, information asymmetry, and trust. The former two are the basic assumptions of agency theory, accounting for the reasons and needs for control in principal-agent relationships. Trust is also an important aspect of principal-agent relationships, even though it is not a basic assumption of agency theory. Prior studies have viewed trust as an antecedent of control intensity, showing that high level of trust would lower the intensity of control (Remus and Wiener, 2012; Rustagi *et al.,* 2008; Wiener *et al.,* 2016).

Overall, these three dimensions can predict the possibility of moral hazard problems happen and the necessity of control in principal-agent relationships. Control intensity is determined accordingly. Goal conflict between clients and designers triggers the designers' opportunistic behaviour (Boatright, 2010). Information asymmetry creates chances for such agency problems to occur (Mahaney and Lederer, 2003). Thus, high control intensity is needed when goal conflict and information asymmetry are strong. Trust, however, reflects the clients' confidence in designers' ability, goodwill, and integrity (Mayer, Davis, and Schoorman, 1995). It will lower the necessity and intensity of clients' control.

Therefore, control intensity is a continuum ranging from high to low. At the upper end of the continuum, control intensity is highest when goal conflict and information asymmetry between clients and designers are high whereas clients have little trust in designers. At the opposite end, little control is needed in design consulting projects.



**Expanded from models of Govindarajan and Fisher (1990); Kirsch (1996).*

Figure 1: Conceptual framework for determining control modes and intensity

Contextualizing the Conceptual Framework in Design Consulting Projects

The conceptual framework should be analysed in the context of design consulting projects to achieve contextualization. It is established mainly based on the existing literature and theoretical foundation. However, its analysis and implementation may be different from theoretical predictions due to the distinctive characteristics of design consulting projects.

Antecedents of control modes: Feasibility of control

Antecedents of control modes may present differently in design consulting projects because of complicated design processes and outputs. It is predicted that outcome control is feasible when the outcome measurability is high (Kirsch, 1996; Ouchi, 1977, 1979). However, the design service is intangible, of which the outcomes are hard to measure and evaluate (Winch and Schneider, 1993). In design consulting projects, what clients purchase are the intangible design services provided by designers rather than a ready-made tangible product, although there are some deliverables (e.g. drawings, models) created (Homburg and Stebel, 2009; Winch and Schneider, 1993). Therefore, in design consulting projects, outcome assessment should emphasize service quality evaluation rather than deliverables measurement. The measurability of overall service quality would determine the utilization of outcome control.

Behaviour observability and the controller's knowledge of the transformation process determine the feasibility of behaviour control (Eisenhardt, 1985; Kirsch, 1996; Ouchi, 1977, 1979). Under most circumstances, it is challenging for clients to observe designers' behaviour and understand design processes (Knotten, Svalestuen, Hansen, and Lædre, 2015). Design is generally an endless iterative process, which is often described as a black box involving problem-finding and problem-solving processes (Sebastian and Prins, 2009; Trebilcock, 2004). Even though clients are pivotal in the design process and co-product with designers, they often cannot fully understand the transformation process (Norouzi, Shabak, Embi, and Khan, 2015). Also, design tasks are knowledge-intensive and creative (Gray and Hughes, 2001; Von Nordenflycht, 2010). For clients who are non-expert in the design domain, designers' behaviour may be opaque and difficult to observe. Thus, behaviour control is relatively less feasible in design consulting projects as two antecedents are both at low levels.

Antecedents of control intensity: Necessity of control

Antecedents of control intensity may be complicated in design consulting projects where agents are professionals (Sharma, 1997). These three dimensions of client-designer relationships are contingent and following a continuum ranging from high to low. Their overall degree determines control intensity at given contexts.

The goal conflict between principals and agents assumed by agency theory is contingent when agents are professionals who have mixed motives (Sharma, 1997). Designers, of course, may not always act in the best interest of principals but prefer to maximize self-interests (Mills, 1990). In this case, the goals of designers and clients are conflicting. However, designers as professionals have service ethics and career pursuits. They may be driven by the pride in the design and a calling to serve others rather than self-interest alone (Sharma, 1997) so that they are intrinsically motivated to provide services without considering self-interest, or at least without sacrificing principals' interest (Fleming, 1996; Von Nordenflycht, 2010). The divergence of goals of principals and agents would be narrowed under this circumstance.

Information asymmetry in agency theory has been expanded as knowledge asymmetry by Sharma (1997) in the case of professionals as agents. This shows the clients' disadvantages in specialized knowledge compared with agents. Knowledge asymmetry is the evolution of information asymmetry, embracing the asymmetry of not only information but also skills for understanding the information (Daal, Haas, and Weggeman, 1998). It is common between clients and designers, owing to their

different domain knowledge (Sharma, 1997). The degree of knowledge asymmetry depends on the clients' knowledge and experiences of design.

The trust between principals and professional agents is also distinctive from mainstream principal-agent relationships. Generally, agency theory is assumed as distrust-based due to agents' self-interest and potential opportunism, so its management philosophy is control-oriented (Davis *et al.,* 1997; Grundei, 2008). However, Reve and Levitt (1984) view the principal-professional relationship as a moral relationship, in which principals trust the capability and faith of the professional agents. Even no trust initially, the interaction and co-production between principals and professional agents would build trust among them (Sharma, 1997). Hence, it is expected that the degree of trust between clients and designers would vary in different contexts.

Overall, the conceptual framework is appropriate to design consulting projects. Its antecedents of control modes and control intensity could reflect the characteristics of client-designer transactions. It enables clients to determine control strategies fitting with the feasibility and necessity of control when agents are professionals.

CONCLUSIONS

Antecedents of control have received much attention in extant studies, examining how to select control modes under specific circumstances. However, varying necessity and intensity of control have been rarely examined so far. Control strategies should include both control modes and intensity, which are determined by the feasibility and necessity of control respectively.

This study develops an expanded conceptual framework for determining control modes and intensity in design consulting projects. Thereinto, control modes selection is determined by the feasibility of control based on models proposed by Govindarajan and Fisher (1990) and Kirsch (1996). Control intensity depends on the necessity of control, which is measured by the nature of client-designer relationships based on agency theory.

This study is the tentative exploration of implementing control strategies in design consulting projects. The proposed conceptual framework would be a significant component of the integrated governance system for design consulting projects. This study enriches the existing knowledge about control strategies and principal-agent relationships. It fills the gap of previous studies on the necessity and intensity of control by developing a conceptual framework which incorporates the feasibility and necessity of control, as well as control modes and intensity. Also, it expands the application of agency theory in design consulting projects where agents are professionals.

The output of this study is limited to a conceptual framework developed based on the literature review and theoretical background. The conceptual framework has not been verified through empirical research. Therefore, future empirical research within design consulting projects is needed to test and revise the current conceptual framework.

REFERENCES

Anderson, E and Oliver, R L (1987) Perspectives on Behaviour-based versus Outcome-based Salesforce Control Systems, *The Journal of Marketing*, 50(**4**), 76-88.

Ballard, G (1998) On the agenda of design management research, *In*: *Proceedings of the 6th Annual Conference of the International Group for Lean Construction*, August 1998, Guaruja Beach, Brazil.

Bergen, M, Dutta, S and Walker, O C (1992) Agency relationships in marketing: A review of the implications and applications of agency and related theories, *The Journal of Marketing*, 56(**3**), 1-24.

Boatright, J R (Ed.) (2010) *Finance Ethics: Critical Issues in Theory and Practice*. Hoboken, NJ: John Wiley and Sons, Inc.

Choudhury, V and Sabherwal, R (2003) Portfolios of control in outsourced software development projects, *Information Systems Research*, 14(**3**), 291-314.

Daal, V, Haas, D and Weggeman (1998) The knowledge matrix: A participatory method for individual knowledge gap determination, *Knowledge and Process Management*, 5(**4**), 255-263.

Das, T K and Teng, B S (2001) Trust, control and risk in strategic alliances: An integrated framework, *Organization Studies*, 22(**2**), 251-283.

Davis, J H, Schoorman, F D and Donaldson, L (1997) Toward a stewardship theory of management, *Academy of Management Review*, 22(**1**), 20-47.

Dekker, H C (2004) Control of inter-organizational relationships: Evidence on appropriation concerns and coordination requirements, *Accounting, Organizations and Society*, 29(**1**), 27-49.

Eisenhardt, K M (1985) Control: Organizational and economic approaches, *Management Science*, 31(**2**), 134-149.

Eisenhardt, K M (1989) Agency theory: An assessment and review, *Academy of Management Review*, 14(**1**), 57-74.

Emmitt, S (2014) *Design Management for Architects*. Chichester, UK: John Wiley and Sons.

Ferris, J M (1992) School-based decision making: A principal-agent perspective, *Educational Evaluation and Policy Analysis*, 14(**4**), 333-346.

Fleming, D (1996) Professional-client discourse in design: Variation in accounts of social roles and material artefacts by designers and their clients, *Text-Interdisciplinary Journal for the Study of Discourse*, 16(**2**), 133-160.

Govindarajan, V and Fisher, J (1990) Strategy, control systems and resource sharing: Effects on business-unit performance, *Academy of Management Journal*, 33(**2**), 259-285.

Gray, C and Hughes, W (2001) *Building Design Management*. Oxford: Butterworth-Heinemann.

Greenwood, R, Li, S X, Prakash, R and Deephouse, D L (2005) Reputation, diversification and organizational explanations of performance in professional service firms, *Organization Science*, 16(**6**), 661-673.

Gregory, R, Beck, R and Keil, M (2013) Control balancing in information systems development offshoring projects, *Management Information Systems: MIS Quarterly*, 37(**4**), 1211-1232.

Grundei, J (2008) Are managers agents or stewards of their principals, J*ournal Für Betriebswirtschaft*, 58(**3**), 141-166.

Homburg, C and Stebel, P (2009) Determinants of contract terms for professional services, *Management Accounting Research*, 20(**2**), 129-145.

Jaworski, B J (1988) toward a theory of marketing control: Environmental context, control types and consequences, *The Journal of Marketing*, 52(**3**), 23-39.

Kirsch, L J (1996) The management of complex tasks in organizations: Controlling the systems development process, *Organization Science*, **7**(**1**), 1-21.

Kirsch, L J (1997) Portfolios of control modes and IS project management, *Information Systems Research*, 8(**3**), 215-239.

Kirsch, L J and Choudhury, V (2010) Toward a theory of relational control: How relationship structure influences the choice of controls, *In*: S Sitkin, L Cardinal and K Bijlsma-Frankema (Eds.) *Organizational Control*, New York: Cambridge University Press.

Kirsch, L J, Ko, D G and Haney, M H (2010) Investigating the antecedents of team-based clan control: Adding social capital as a predictor, *Organization Science*, **21**(**2**), 469-489.

Knotten, V, Svalestuen, F, Hansen, G K and Lædre, O (2015) Design management in the building process - A review of current literature, *Procedia Economics and Finance*, **21**, 120-127.

Macmillan, S (Ed.) (2004) *Designing Better Buildings: Quality and Value in the Built Environment*. New York: Taylor and Francis.

Mahaney, R C and Lederer, A L (2003) Information systems project management: An agency theory interpretation, *Journal of Systems and Software*, 68(**1**), 1-9.

Mayer, R C, Davis, J H and Schoorman, F D (1995) An integrative model of organizational trust, Academy of Management Review, 20(**3**), 709-734.

McGeorge, J F (1988) Design productivity: A quality problem, *Journal of Management in Engineering*, 4(**4**), 350-362.

Mills, P K (1990) On the quality of services in encounters: An agency perspective, *Journal of Business Research*, 20(**1**), 31-41.

Ning, Y (2017a) Combining formal controls and trust to improve dwelling fit-out project performance: A configurational analysis, *International Journal of Project Management*, 35(**7**), 1238-1252.

Ning, Y (2017b) Selecting client's project control strategies in person-to-organization transactions, *International Journal of Project Management*, 35(**2**), 212-220.

Norouzi, N, Shabak, M, Embi, M R B and Khan, T H (2015) The architect, the client and effective communication in architectural design practice, *Procedia - Social and Behavioural Sciences*, 172, 635-642.

Ouchi, W G (1977) The relationship between organizational structure and organizational control, *Administrative Science Quarterly*, 22**(1**), 95-113.

Ouchi, W G (1979) A conceptual framework for the design of organizational control mechanisms, *Management Science*, 25**(9**), 833-848.

Ouchi, W G and Maguire, M A (1975) Organizational control: Two functions, *Administrative Science Quarterly*, 20(**4**), 559-569.

Quinn, J J (2011) Principal-agent theory. *In*: J T Ishiyama and M Breuning (Eds.) *21st Century Political Science: A Reference Handbook*, Los Angeles: SAGE Publications, Inc.

Remus, U and Wiener, M (2012) The amount of control in offshore software development projects, *Journal of Global Information Management*, 20(**4**), 1-26.

Reve, T and Levitt, R E (1984) Organization and governance in construction, International *Journal of Project Management*, 2(**1**), 17-25.

Rustagi, S, King, W R and Kirsch, L J (2008) Predictors of formal control usage in it outsourcing partnerships, *Information Systems Research*, 19**(2**), 126-143.

Schillemans, T (2013) Moving beyond the clash of interests: On stewardship theory and the relationships between central government departments and public agencies, *Public Management Review*, 15(**4**), 541-562.

Schneider, S M (2007) *Perceptions of Software Developers and Direct Managers in Successful and Failed Software Development Projects: An Agency Theory Perspective*, PhD Thesis, Northcentral University, Prescott, Arizona.

Sebastian, R and Prins, M (2009) Collaborative architectural design management. *In*: S Emmitt, M Prins and A Den Otter (Eds.) *Architectural Management: International Research and Practice*, Chichester, UK: John Wiley and Sons.

Sharma, A (1997) Professional as agent: Knowledge asymmetry in agency exchange, *Academy of Management Review*, 22(**3**), 758-798.

Toivonen, A and Toivonen, P U (2014) The transformative effect of top management governance choices on project team identity and relationship with the organization - an agency and stewardship approach, *International Journal of Project Management*, 32(**8**), 1358-1370.

Trebilcock, P (2004) Managing design and construction. In: S Macmillan (Ed.) *Designing Better Buildings: Quality and Value in the Built Environment*. London: Taylor and Francis Group.

Tuuli, M M, Rowlinson, S and Koh, T Y (2010) Control modes and mechanisms in construction project teams: Drivers and consequences, *Construction Management and Economics*, 28(**5**), 451-465.

Van Slyke, D M (2006) Agents or stewards: Using theory to understand the government-non-profit social service contracting relationship, *Journal of Public Administration Research and Theory*, 17(**2**), 157-187.

Von Nordenflycht, A (2010) What is a professional service firm? toward a theory and taxonomy of knowledge-intensive firms, *Academy of Management Review*, 35(**1**), 155-174.

Waterman, R and Meier, K (1998) Principal-agent models: An expansion, *Journal of Public Administration Research and Theory*, 8(**2**), 173-202.

Wiener, M, Mähring, M, Remus, U and Saunders, C S (2016) Control configuration and control enactment in information systems projects: Review and expanded theoretical framework, *Management Information Systems: MIS Quarterly*, 40(**3**), 741-774.

Winch, G and Schneider, E (1993) Managing the knowledge-based organization: The case of architectural practice, *Journal of Management Studies*, 30(**6**), 923-937.

EXAMINING CONSTRUCTION AND PROJECT MANAGEMENT PERSPECTIVES OF PROJECT-BASED FAILURE

Danstan Chiponde, Barry Gledson[1] and David Greenwood

Faculty of Engineering and Environment, Northumbria University, Ellison Place, Newcastle Upon Tyne, NE1 8ST, UK

Projects are distinctive, time-constrained, undertakings meant to generate benefits for their stakeholders. They are delivered by Project-based organisations (PBOs) whose various actors separately consider achievement in relation to a project's outputs, outcomes, and impact. For example, contracting organisations typically consider projects that fail to meet their principal cost and time targets as having been unsuccessful, whereas the various sponsors, customers, collaborators, and end-users may instead base their evaluation upon the ultimate operational results of these same projects. The aim was to examine the knowledge base for contrasting perspectives around project-based failure in the construction sector. This required scrutiny and analysis of the extant literature, using a systematic-type literature review approach within and across construction management (CM) and project management (PM) literature. This revealed that in PM literature, considerations of failure are often more introspective and discussed in more general terms; with its main causes being associated with the PM function itself. Whereas the CM literature instead focuses on more specific and external failures; with causes more likely attributed to the wider supply chain and contextual factors. Results can help inform the design of dedicated research instruments to help better understand the impact of failure on PBOs.

Keywords: failure, organisational learning, performance, success

INTRODUCTION

Projects pervade across society (Jensen *et al.,* 2016) and their success, or lack thereof, impacts upon organisational performance and wider economic activity. Thus, key factors such as project managers (PMs), and specific to the construction sector, construction managers (CMs), regularly review progress to try to ensure delivery success. Unfortunately, project-related failures are frequent despite ever-improving education and training to prevent this (Shore, 2008). Much prior research has focused on project success factors, particularly focussing on the PM function (Jugdev and Muller, 2005) with, as Turner and Zolin (2012) point out, similar analysis of the CM function being far rarer. To address this, the present study adopts both PM and CM perspectives in focusing on project failure: A topic that itself, according to Velikova *et al.,* (2018) is rarely considered and poorly understood.

[1] barry.gledson@northumbria.ac.uk

Chiponde, D, Gledson, B and Greenwood, D (2019) Examining Construction and Project Management Perspectives of Project-Based Failure *In:* Gorse, C and Neilson, C J (Eds) *Proceedings of the 35th Annual ARCOM Conference,* 2-4 September 2019, Leeds, UK, Association of Researchers in Construction Management, 649-657.

The construction sectors importance, performance, and its considerations of success and failure

The construction sector is important to any nation's economy since it contributes to the Gross Domestic Product (GDP) and creates employment through the provision of its services. For example, in 2017 UK construction accounted for; £113 billion of the value of the economy (6% of the total), 2.4 million jobs and 1 million construction businesses (Rhodes, 2018). Fuelled by population growth, urbanisation and efforts to mitigate the physical impacts of climate change, its importance will continue; with an estimated $78 trillion to be spent on infrastructure between 2014 and 2025 worldwide (PWC, 2014; KPMG, 2017). Unfortunately, it experiences many failures. For example, Ojiako *et al.,* (2008) identified: the London Millennium Bridge; the London Millennium Dome; Wembley Stadium, and; the Scottish Parliament buildings as notable projects that have publicly experienced failure. Reviewing failure in construction reveals that it can be broad and multi-faceted, and of any scale. For example, more recent instances of construction -related failures include the Grenfell tower fire disaster, with 70 lives lost and the Carillion liquidation with 2,782 job losses and £65m redundancy costs (Gerrard, 2018b, Gerard, 2019, Mor *et al.,* 2018). Additionally, it is reported that the presently delayed Crossrail project requires £1bn extra funding indicating that it too may encounter failure (Gerrard, 2018a). Evidently, in construction, failure can range from design, engineering, or technological type failures (Minato, 2003; Love *et al.,* 2008; Shohet and Paciuk, 2006) to business failures with value not realised from investment (Holt, 2013; Alaka *et al.,* 2015, 2016), or beyond.

Traditionally project success or failure has been considered based upon the achievement or otherwise of outputs (i.e. the time-cost-quality triad), however, now, achievements are also considered in relation to a project's outcomes and impact (DBIS, 2010). To clarify, Turner and Zolin (2012) view project output as being the newly built assets immediate and tangible project results as measured at the end of a project in terms of time, cost, and quality (Baccarini, 1999). Project outcomes are instead the new capabilities gained after investing in the project as a result of the project outputs (DBIS, 2010), while impact(s) enable(s) project beneficiaries to do new things, solve problems and are mostly measured months or years post project completion (Turner and Zolin, 2012). Emphasising these distinctions, Baccarini (1999) contends that achieving project outputs is considered more as project management success whilst the realisation of outcomes and impact is instead project success. Additionally, end users tend to focus more on performance (outcome and impact) or project success while the PM delivery team focuses on the project outputs achieved as measures of project management success (Baccarini, 1999; Turner and Zolin, 2012). Evidently, perceptions of project success (or failure) vary between stakeholders because of their own perspectives, and also fluctuate throughout stages of the projects life cycle (Lim and Mohamed, 1999; Gupta *et al.,* 2018). Thus, PMs and CMs should consider this wider spectrum of failure/success variables (including outcomes and impact) and not just the narrow efficiency measures of the iron triangle. Hence, for this studys focus, any lack of intended achievement(s) in one or more of, output, outcome and impact, be it small or large, constitutes an example of project-related failure.

METHODOLOGY

A systematic literature review (SLR) type approach, as described by Bryman (2012; and Oraee *et al.,* (2017) was used for the study which is viewed as an appropriate

research methodology for analysing and synthesising knowledge (Mostafa *et al.,* 2016; Xia *et al.,* 2018). Based on Bryman (2012) discussion of a SLR-type approach, Stage 1 involved defining the purpose of the research which, was to review project failure in construction project management from the perspectives of project- and construction- managers. Stage 2 involved seeking out relevant articles using the keyword search, "Project Failure". In order to obtain these materials, whilst keeping the scope of the operation within reasonable limits, leading journal ranking websites were consulted to determine the 10 most appropriate journals (5 relating to each of the PM and CM domains). Stage 3 involved appraising the articles sourced in Stage 2 for relevance to the research, based on titles relative to failure and the construction industry as per exclusion/inclusion criterion (of correct sector, and the topic being related to both construction, and failure). A further check for duplication and appropriateness of articles sourced was performed by reviewing abstracts and main contents. Thus, the search for key journal articles about failure in PM literature gave an initial total of 418 articles with 10 appropriate articles, having satisfied the exclusion/inclusion criteria, ultimately being selected from the: International Journal of Managing Projects in Business (108 potential articles identified, with 2 appropriate articles selected), International Journal of Project Management (260 identified; 5 selected), Journal of Project Management (42 identified; 2 selected) and Scandinavian Journal of Management (8 identified; 1 selected). A similar search on failure in the CM literature yielded 112 initial articles, filtered down to the most appropriate 14 as follows: Building Research and Information (3 identified; 1 selected), Construction Innovation: Information, Process, Management (5 identified; 2 selected), Construction Management and Economics (28 identified; 1 selected), Engineering, Construction and Architectural Management (35 identified; 5 selected), and ARCOM conference proceedings (41 identified; 5 selected). In total therefore, 24 articles were selected for use in Stage 4, analysis and synthesis.

FINDINGS AND DISCUSSION

When analysing the following aspects were considered: A) research approach; b) their manifest understanding of failure; c) the identified causes of failure, or; d) any recommended mitigation measures. Each is now discussed in turn:

Research approaches and areas of focus

PM literature had much interest on identifying critical failure factors (CFF) or, project success/failure factors (PSFF) (Chen, 2015) revealing a positivist perspective that frequently focused on the need for upskilling of the PM, yet often neglected contextual factors. CM literature also evidenced some focus on failure prediction, and CFF identification models (Trangkanont and Charoenngam, 2014; Lindhard and Larsen, 2016), but by also advocating for managerial and social factors to be considered in failure mitigation, interpretivism was apparent (Chipulu *et al.,* 2014; Saunders *et al.,* 2016). Thus, pragmatic and pluralistic approaches are recommended for undertaking research around project-related failure. Further, research in both PM and CM literature is mostly qualitative, with empirical data usually derived from case studies and semi-regular questionnaire surveys based on purposive sampling observed.

Understanding around failure: Perception, indicators and types

In PM literature, Chipulu *et al.,* (2014) observes there are no singular agreed criteria for measuring success or failure and so variables that merely indicate success or failure on projects are developed, such as: wider society/economic factors, organisational goals, project level- scope, time, cost, quality, risk, safety,

communication, leadership, decision-making, and project team effectiveness. Regarding failure types organisational death and associated synonyms were considered (Dalcher, 2012; Lechler and Thomas, 2015). Poor quality, delays and cost overrun(s) were typically highlighted (Orouji, 2016; Mahmoudi and Feylizadeh, 2017) with inadequate quality mainly considered amongst PM literature as the biggest form of failure (Belassi and Tukel 1996). In the CM literature no singular agreed definition and measure of failure was apparent with instead specific manifestations of failure, such as time delays instead being more prominent (Ansah and Sorooshian, 2018). Razak *et al.,* (2016, p. 835) did offer a definition of failure as "a lack of success, falling short, or omission of some persons, processes or products". Trangkanont and Charoenngam (2014, p. 422) also define program failure as "set of program objectives that were not hierarchically met", citing in their study, failures to meet a projects objective of ensuring low-income earners access to housing and ownership as an example of failure in project outcomes and impact. CM literature also acknowledged business-level failures, giving it much attention, with terms such as bankruptcy, insolvency and financial distress used (Dikmen *et al.,* 2010; Alaka *et al.,* 2016). Love *et al.,* (2008) focused instead on procedural failures such as task errors, omissions, and oversimplifications. Other failures focus on failing to meet customers' requirements around product quality (Razak *et al.,* 2016). It was noted therefore that CM literature is more specific about failure types (defects, delays, costs) when compared to the PM literature. As expected, cost and time overruns were frequently highlighted in both PM and CM literature (Ansah and Sorooshian, 2018) as the common type of failures (Love *et al.,* 2008) and as measures of success/failure (Nahyan *et al.,* 2012). Evidently, both PM and CM research tends to focus on outputs instead of outcomes and impacts in perceiving project failure/success with CM literature particularly focused on financial outcomes (Dalcher 2012).

Causes (and effects) of project failure

Within PM literature there are many causes of project failure, with technical and engineering factors being frequently considered (Sauser *et al.,* 2009). The PM function itself receives attention (Belassi and Tukel, 1996), with Sage *et al.,* (2014) referring to the managerialisation of failure, where failure is attributed purely as a result of project management practices. However, other project parties, culture and contextual factors are also known to lead to failure. CM literature instead attributed various external actors as causes of failure, including designers, labourers, suppliers, subcontractors and the client (Trangkanont and Charoenngam, 2014). Conflicting goals, weather, lack of information, competition, site conditions, social-economic and partnering challenges (Ansah and Sorooshian, 2018) were also cited. Changes in law, politics, procurement strategy, interest rates, and inflation are other causes, note Trangkanont and Charoenngam (2014), especially on larger projects. Other causes include design capacity, bureaucracy, design changes, errors, corruption (Nguyen and Chileshe, 2013) supply chain, decision making, (Dikmen *et al*., 2010) cost cutting, non-compliance and unreasonable contractual constraints (Layzell and Ledbetter, 1998a). According to Nguyen and Chileshe (2013), these issues can be summarised as being related to knowledge and technical; management; financial and economic, and; social and legal matters. However, it is again worth emphasising that PM literature often views the project manager themselves as a root cause (Sage *et al.,* 2014) while CM literature attributes other parties in the supply chain as more likely being the root causes of failure (Dikmen *et al.,* 2010). Considering effects of failure, both PM and CM literature focused on project outputs, particularly cost. Other effects in terms of quality and delay are also viewed in terms of costs. For example, Lindhard and

Larsen (2016) noted that quality-related failures add costs of between 3.6-6.6% and delays add 16-23% to total project costs. Reported effects of failure included customers dissatisfaction, company reputations, and unsatisfactory safety performance, as apparent in both the PM and CM literature (Bell and Taylor, 2011; Trangkanont and Charoenngam, 2014; Saunders *et al.,* 2016).

Mitigation of project failure

According to Sage *et al.,* (2014) the most common approach to mitigating or avoiding project failure is upskilling the PM equipping them with standardized knowledge, and tools. Belassi and Tukel (1996) contend that organisational commitment is vital in attempting to mitigate project related failure, and Sauser *et al.,* (2009) suggest that a contingency approach be adopted to project management be adopted. In contrast, CM literature suggested improvement to the supply chain and external project environment is necessary (Rwelamila *et al.,* 1999; Dikmen *et al.,* 2010). Ansah and Sorooshian (2018) and Mahmoudi and Feylizadeh (2017) both recommended better attention to scheduling and planning practices be adhered to, with Lindhard and Larsen (2016) echoing the need for clarity in success/failure definition and measurement. Motivation and risk management (Nguyen and Chileshe, 2013) were also cited. Furthermore, notable models for mitigating failure were found including: Ansah and Sorooshians (2018) 4Ps (Project Related; Participants, Practices and Procurement) model for analysing delays; Failure Mode and Effects Analysis by Layzell and Ledbetter (1998) for defects; Construction Industry Bankruptcy Prediction Models (CI-BPMs) by Alaka *et al.,* (2015) for business failure; and Enterprise Resource Planning (ERP) model by (Orouji, 2016) in managing cost and time- failures. Overall, since the value chain influences failure (Dikmen *et al.,* 2010), a holistic approach should be considered instead of focusing on upskilling.

Implications - A call for active learning from project failures

Even with the advancement in technology and PM training, failure still occurs (Shore, 2008). Evidently, without the ability to extract learning from project-related failures, upskilling PM practitioners alone will not mitigate failure: As certain failures still exist regardless of skill levels (Love *et al.,* 2008). Failure mitigation models also require learning (Layzell and Ledbetter 1998). Hence, proactive prevention of failure by way of active learning is recommended since, as Dalcher (2012) points out, lessons from past failed projects can potentially improve capabilities to manage future challenges. Furthermore, there is merit in adopting a holistic approach that embraces what March (1991) refers to as exploratory and exploitative learning, as well as Stead and Smallmans (1999) concept of isomorphic; learning that comes from both personal failures and those of others. Table 1 summarises the reviewed literature on project-related failures and contrasts the different perspectives between PM and CM literature.

Table 1: Contrasting Understanding of failure based on PM and CM Literature

	Research	Definition	Types	Causes	Mitigation
PM	Positivism - CSFF	Non-standardised.	Generic mainly on quality	PM practice failure	Upskilling the PM
CM	Positivism - CSFF	Non-standardised.	Specific - cost, delays, defects.	Supply chain oriented	Wider supply chain action.

CONCLUSION

The results from the SLR across PM and CM literature accord with the assertion of Bakker *et al.,* (2016) that research on project failures is mainly qualitative. As identified by Hall *et al.,* (2012) and Liu *et al.,* (2017) findings are generally derived

from empirical case studies, and, as observed by Gupta *et al.,* (2019) these provide limited generalisability. In PM literature, considerations of failure are often of an introspective nature with the main causes of it, often identified as being associated with the PM function itself or simply caused by poor project management practices. In contrast, the CM literature focuses more on more specific, and external, instances of failures, with causes often attributed back to the wider context or the involvement of the supply chain. Being mindful of all of these aspects should help inform any future follow-on work, in either domain or across both. Specifically, this should help inform research that seeks to better understand construction and project related failure. They are particularly useful for the subsequent data collection stage of the current doctoral work which seeks to more fully understand how failures and learning affects PBOs.

REFERENCES

Alaka, H, Oyedele, L, Toriola-Coker, O, Owolabi, H, Akinade, O, Bilal, M and Ajayi, S (2015) Methodological approach of construction businesses failure prediction studies: A review *In:* Raiden, A and Aboagye-Nimo, E (Eds.), *Proceedings 31st Annual ARCOM Conference*, 7-9 September 2015, Lincoln, UK Association of Researchers in Construction Management, 1291-1300.

Alaka, H A, Oyedele, L O, Owolabi, H A, Ajayi, S O, Bilal, M and Akinade, O O (2016) Methodological approach of construction business failure prediction studies: A review, *Construction Management and Economics*, *34*(**11**), 808-842.

Ansah, R H and Sorooshian, S (2018) 4P delays in project management, *Engineering, Construction and Architectural Management*, 25(**1**), 62-76.

Baccarini, D (1999) The logical framework method for defining project success, *Project Management Journal*, 30(**4**), 25-32.

Belassi, W and Tukel, O I (1996) A new framework for determining critical success/failure factors in projects, *International Journal of Project Management*, 14(**3**), 141-151.

Bell, E and Taylor, S (2011) Beyond letting go and moving on: New perspectives on organizational death, loss and grief, *Scandinavian Journal of Management*, 27(**1**), 1-10.

Bryman, A (2012) *Social Research Methods 4th Edition*. Oxford: Oxford University Press.

Chen, H L (2015) Performance measurement and the prediction of capital project failure, *International Journal of Project Management*, 33(**6**), 1393-1404.

Chipulu, M, Ojiako, U, Gardiner, P, Williams, T, Mota, C, Maguire, S, Shou, Y, Stamati, T and Marshall, A (2014) Exploring the impact of cultural values on project performance: The effects of cultural values, age and gender on the perceived importance of project success/failure factors. *International Journal of Operations & Production Management*, 34(**3**), 364-389.

Dalcher, D (2012) The nature of project management: A reflection on The Anatomy of Major Projects by Morris and Hough, *International Journal of Managing Projects in Business*, 5(**4**), 643-660.

Department for Business Innovation and Skills (2010) *Guidelines for Manageing Programmes - Understanding Programmes and Programme Management*, Guidelines for Managing Programmes, Department for Business Innovation and Skills, UK

Dikmen, I, Talat Birgonul, M, Ozorhon, B and Egilmezer Sapci, N (2010) Using analytic network process to assess business failure risks of construction firms, *Engineering, Construction and Architectural Management*, 17(**4**), 369-386.

Gerrard, N (2018a) *Crossrail Needs £1bn More, Faces Further Delays*, Construction Manager. Available from http://www.constructionmanagermagazine.com/news/crossrail-could-be-delayed-beyond-2019/ [Accessed: 17 January 2019].

Gerrard, N (2018b) *Grenfell One Year on: How Has Construction Changed?* Global Construction Manager, Available from http://www.globalconstructionreview.com/news/grenfell-one-year-how-has-construction-changed/ [Accessed 14/07/2019].

Gerrard, N (2019) *How Has Construction Changed Since Carillions Collapse?*, Construction Manager, 6-8. Global Construction Manager, Available from http://www.globalconstructionreview.com/news/how-has-construction-changed-carillions-collapse/ [Accessed 14/07/2019].

Gupta, S K, Gunasekaran, A, Antony, J, Gupta, S, Bag, S and Roubaud, D (2019) Systematic literature review of project failures: Current trends and scope for future research, *Computers & Industrial Engineering*, 127, 274-285.

Gupta, S K, Gunasekaran, A, Antony, J, Gupta, S, Bag, S and Roubaud, D (2019) Systematic literature review of project failures: Current trends and scope for future research, *Computers & Industrial Engineering*, 127, 274-285.

Hall, M, Kutsch, E and Partington, D (2012) Removing the cultural and managerial barriers in project-to-project learning: A case from the UK public sector, *Public Administration*, 90(**3**), 664-684.

Holt, G D (2013) Construction business failure: Conceptual synthesis of causal agents, *Construction Innovation*, 13(**1**), 50-76.

Jensen, A, Thuesen, C and Geraldi, J (2016) the projectification of everything: Projects as a human condition, Project Management Journal, 47(**3**), 21-34.

Jugdev, K and Muller, R (2005) a retrospective look at our evolving understanding of project success, *Project Management Journal*, 36(**4**), 19-31.

KPMG (2017) *Project Management Survey Report 2017: Driving Business Perf*ormance. KPMG.

Layzell, J and Ledbetter, S (1998a) FMEA applied to cladding systems - Reducing the risk of failure, *Building Research and Information*, 26(**6**), 351-357.

Layzell, J and Ledbetter, S (1998b) FMEA applied to cladding systems - reducing the risk of failure FMEA applied to cladding systems - reducing the risk of failure, *Building Research and Information*, 26(**6**), 351-357.

Lechler, T G and Thomas, J L (2015) Examining new product development project termination decision quality at the portfolio level: Consequences of dysfunctional executive advocacy, *International Journal of Project Management*, 33(**7**), 1452-1463.

Lim, C S and Mohamed, M Z (1999) Criteria of project success: An exploratory re-examination, *International Journal of Project Management,* 17(**4**), 243-248.

Lindhard, S and Larsen, J K (2016) Identifying the key process factors affecting project performance, *Engineering, Construction and Architectural Management*, 23(**5**), 657-673.

Liu, J, Geng, L, Xia, B and Bridge, A (2017) Never let a good crisis go to waste: Exploring the effects of psychological distance of project failure on learning intention. *Journal of Management in Engineering*, 33(4), 04017006.

Love, P E D, Davis, P R, Lopez, R and Jasper, T (2008) It's not just about bricks and mortar: procedural failures in construction. *In:* Dainty, A (Ed.), *Proceedings 24th Annual ARCOM Conference*, 1-3 September 2008, Cardiff, UK. Association of Researchers in Construction Management, Vol. 2, 779–88.

Mahmoudi, A and Feylizadeh, M R (2017) A mathematical model for crashing projects by considering time, cost, quality and risk, *Journal of Project Management*, 2, 27-36.

Minato, T (2003) Representing causal mechanism of defective designs: A system approach considering human errors, *Construction Management and Economics*, 21(**3**), 297-305.

Mor, F, Conway, L, Thurley, D and Booth, L *(*2018) *The Collapse of Carillion*, Briefing Paper No. 8206, House of Commons Library.

Mostafa, S, Chileshe, N and Abdelhamid, T (2016) Lean and agile integration within offsite construction using discrete event simulation A systematic literature review, *Construction Innovation*, 16(**4**), 483-525.

Al Nahyan, M T, Sohal, A S, Fildes, B N and Hawas, Y E (2012) Transportation infrastructure development in the UAE: Stakeholder perspectives on management practice, *Construction Innovation*, 12(4), 492-514.

Nguyen T P and Chileshe N (2013) Revisiting the critical factors causing failure of construction projects in Vietnam. *In:* Smith, S D and Ahiaga-Dagbui, D D (Eds.) *Proceedings 29th Annual ARCOM Conference*, 2-4 September 2013, Reading, UK, Association of Researchers in Construction Management, 929-938.

Ojiako, U, Johansen, E and Greenwood, D (2008) A qualitative re-construction of project measurement criteria, *Industrial Management and Data Systems*, 108(**3**), 405-417.

Oraee, M *et al (*2017) Collaboration in BIM-based construction networks: A bibliometric-qualitative literature review, *International Journal of Project Management*, 35(**7**), 1288-1301.

Orouji, M (2016) Critical success factors in data management, *Journal of Project Management*, 1(2016), 35-40.

PwC (2014) *Capital Project and Infrastructure Spending Outlook to 2025*. PwC/Oxford Economics.

Razak, D S A, Mills, G and Roberts, A (2016) External Failure Cost in Construction Supply Chains. *In:* Chan, P W and Neilson, C J (Eds.), *Proceedings 32nd Annual ARCOM Conference*, 5-7 September 2016, Manchester UK. Association of Researchers in Construction Management, 833-842.

Rhodes, C (2018) *Construction Industry: Statistics and Policy*, Briefing Paper.

Rwelamila, P D, Talukhaba, A A and Ngowi, A B (1999) Tracing the african project failure syndrome: The significance of ubuntu, *Engineering, Construction and Architectural Management*, 6(**4**), 335-346.

Sage, D, Dainty, A and Brookes, N (2014) A critical argument in favor of theoretical pluralism: Project failure and the many and varied limitations of project management, *International Journal of Project Management*, 32(**4**), 544-555.

Saunders, F C, Sherry, A H and Gale, A W (2016) Dualities and dilemmas: Contending with uncertainty in large-scale safety-critical projects, *Construction Management and Economics*, 34(**9**), 657-675.

Sauser, B J, Reilly, R R and Shenhar, A J (2009) Why projects fail? How contingency theory can provide new insights - A comparative analysis of NASAs Mars Climate Orbiter loss, *International Journal of Project Management*, 27(**7**), 665-679.

Schoper, Y G *et al (*2018) Projectification in Western economies: A comparative study of Germany, Norway and Iceland, *International Journal of Project Management*, 36(**1**), 71-82.

Shohet, I M and Paciuk, M (2006) Service life prediction of exterior cladding components under failure conditions, *Construction Management and Economics*, 24(**2**), 131-148.

Shore, B (2008) Systematic biases and culture in project failures, *Project Management Journal*, 39(**4**), 5-16.

Stead, E and Smallman, C (1999) Understanding business failure: Learning and un-learning from industrial crises, *Journal of Contingencies and Crisis Management*, 7(**1**), 1-18.

Trangkanont, S and Charoenngam, C (2014) Critical failure factors of public-private partnership low-cost housing program in Thailand, *Engineering, Construction and Architectural Management*, 21(**4**), 421-443.

Turner, R and Zolin, R (2012) Forecasting success on large projects: Developing reliable scales to predict multiple perspectives by multiple stakeholders over multiple time frames, *Project Management Journal*, 43(**5**), 87-99.

Velikova, M, Baker, H and Smith, S D (2018) The Meaning of Failure: Establishing a Taxonomy of Failure in the Construction Industry to Improve Organisational Learning. *In:* Gorse, C and Neilson, C J (Eds.), *Proceedings 34th Annual ARCOM Conference*, 3-5 September 2018, Queen's University, Belfast, UK. Association of Researchers in Construction Management, 16–25.

Xia, N, Zou, P X, Griffin, M A, Wang, X and Zhong, R (2018) Towards integrating construction risk management and stakeholder management: A systematic literature review and future research agendas. *International Journal of Project Management*, 36(**5**), 701-715.

TOWARDS IMPROVING SCHEDULE PERFORMANCE OF CONSTRUCTION PROJECTS IN UGANDA WITH LEAN CONSTRUCTION

Jerusha Abarinda[1], Nathan Kibwami[2] and Apollo Tutesigensi[3]

[1] *Construction Economics and Management, School of Built Environment, Makerere University, PO Box 7062, Kampala, Uganda*

[2] *School of Built Environment, College of Engineering, Design, Art, and Technology, Makerere University, PO Box 7062, Kampala, Uganda.*

[3] *School of Civil Engineering, University of Leeds, LS2 9JT, Leeds, UK*

Schedule performance of construction projects in Uganda, is wanting - most projects are not completed within their original contract durations. A growing body of research suggests that such poor performance could be addressed by implementing lean construction. However, evidence suggests that such implementation needs to be carefully designed to take contextual project environment factors into account. In this paper, we report on how lean construction can be applied to ensure timely completion of construction projects in Uganda, considering the project environment factors surrounding construction practice. The research approach that was adopted was mixed-methods, and thus involved a variety of data collection methods - participant observation, structured interviews, and questionnaires. The subjects were contractors that had ongoing projects in 2016. Construction practices were assessed, project environment factors impacting their projects identified, and their compatibility with standard lean tools assessed. The findings reveal that design changes due to inadequate initial planning were among the leading causes of poor schedule performance and that contractors lacked discipline to work within timeframes. Lean tools that were found to be applicable and thus recommended were value stream mapping to remove unnecessary processes and use of the last planner and collaborative planning tools. A strategy for integrating lean construction in the construction practice, cognizant of the environmental factors, was argued for based on the most appropriate lean tools suitable for the identified project environment factors. The research contributes to the understanding that project environment factors cannot be ignored because they affect project performance and consideration of these factors enhances effectiveness of lean construction techniques.

Keywords: lean construction, project delays, schedule performance, Uganda

INTRODUCTION

The construction industry is a slow-progressing industry and is characterised by frequent problems like insufficient quality, time overruns and poor safety. These characteristics limit value delivered to customers (Latham, 1994; Forsberg and Saukkoriipi 2007; Egan, 2008; Ouwor, 2016). The construction industry is constantly facing serious concerns of delays, which are a chronic problem that has negative

[1] abarindajerusha@gmail.com

Abarinda, J, Kibwami, N and Tutesigensi, A (2019) Towards Improving Schedule Performance of Construction Projects in Uganda with Lean Construction *In:* Gorse, C and Neilson, C J (Eds) *Proceedings of the 35th Annual ARCOM Conference,* 2-4 September 2019, Leeds, UK, Association of Researchers in Construction Management, 658-667.

effects on projects, especially in developing countries (Ghenbasha, *et al.,* 2016). Despite new and advanced technologies such as Building Information Modelling, lean construction, modular construction (Aouad *et al.,* 2006; Lee, 2008) applied in the construction industry, the efficiency has remained quite low (Sacks and Goldin, 2007; Guo, 2009). It is observed from studies by previous scholars (see Saukkoriipi (2007) and Guo (2009)) that the construction industry has always had challenges, despite continuous attempts by participants in the industry to find remedies and improve performance.

Uganda's construction industry faces challenges similar to those faced worldwide. Alinaitwe, *et al.,* (2010) highlighted problems in productivity, innovation, slipping schedules, disputes, high costs of production and rework as some of the factors affecting the construction industry in Uganda. Meanwhile, Muhwezi, *et al.,* (2013) observe that wastage in construction extends to labour, time, capital and machinery. Ssemwogerere (2011) also observes that delay in completion of projects in Uganda is a big problem, as it is in the construction industry worldwide. Delays impact directly on contractors and clients alike because these participants incur extra costs since delays always end up in increased project cost. Additionally, the client faces revenue loss from delayed project completion. It is therefore necessary to find solutions to mitigate delays and save stakeholders such unnecessary additional costs.

Lean construction has been recommended by many researchers as one of the approaches that can be adopted to improve overall performance in the construction industry in general, and adherence to schedules in particular (Koskela 1992, 2000; Ballard, 2000; Koskela and Howell, 2011). However, it is not enough to just copy methods of practice. For instance, Engineer Ohno, the father of the Toyota Production System framework, observed that it was dangerous to copy existing models without understanding their importance and how they fit in the grand scheme. Therefore, methods must be adapted to the existing practices and should be practical. Lean construction therefore ought to be viewed as a process undergoing continuous improvement with applications tailored and adapted to suit different environments and cultures.

Lean construction has received little to no attention in the Ugandan construction industry. Given the benefits that have been derived from applying lean construction around the world (Aziz and Hafez, 2003, Luo *et al.,* 2005, Womack and Jones, 2010), we contend that the Ugandan construction industry is missing out and it is high time lean construction was considered seriously as a means to improve project schedule performance in the construction industry in Uganda. Although the Ugandan construction industry has similar characteristics as the industry in other countries, processes of delivery differ because of cultural and environmental differences. As such, successful implementation of lean construction in Uganda requires one to, not only, understand the methods and processes used to execute projects, but also consider project environment factors affecting practice in order to facilitate harmonious integration. Against this background, the research reported in this paper was aimed at exploring the potential of lean construction to improve project schedule performance in Uganda's construction projects. To facilitate achievement of this aim, the following specific objectives were set:

1. To identify project environment factors which are critical for project schedule performance in Uganda;

2. To identify lean approaches that can be applicable to the critical environment factors that influence project schedule performance; and
3. To propose a strategy for lean construction integration into construction projects so as to improve project schedule performance.

This paper focuses on objectives 1 and 2, and findings from the first two objectives will inform objective 3, which forms part of broader ongoing research.

Lean Construction and Its Limitations

Lean construction has received attention as a modern method to improve construction performance and productivity (Abd el-Razek *et al.,* 2008). The promises of lean - using smaller workforces, less space while transforming existing operations and obtaining great improvements in the areas of quality, productivity and others (Womack and Jones, 2010) - drew attention from construction practitioners (Koskela,1992; Ballard and Howell, 1998). Lean tools are regarded as means through which lean theory is implemented. The main aim of lean theory is to maximize value while reducing waste, by using appropriate lean tools. Lean construction provides a proactive rather than reactive approach in construction, thereby identifying potential problems before they occur and ensuring their occurrence is controlled (Gamal, 2013). A systematic review of lean implementation by Babalola *et al.,* (2018) mentions the commonly used tools like value stream mapping, autonomation, pull system signalling, last planner system, Just in Time and collaborative planning. These tools could be implemented as standalone practices or integrated systems. However, despite the lean recommendations by researchers and attempts to implement them, the construction industry continues to face problems of delays. This calls for further research on context in which lean should be applied as there are potentially many variables that influence its application.

The transition to lean requires radical change, which involves total reshaping of purpose, systems and work culture. Nordin and Deros (2017) suggest that a company that intends to implement lean must put emphasis on change readiness, leadership and management, change agent systems and communication, among others. Alinaitwe (2009) notes that although lean construction efforts could prove to be highly rewarding in Uganda's construction industry, application of lean construction is risky and can be disastrous if not properly managed. Implementation of lean construction requires leadership commitment and is sustained by a culture of continuous improvement (Aziz and Hafez, 2013). Although lean is now popular in the construction industry, there are cultural and structural barriers against its implementation despite the geographical area (Sarhan and Fox, 2013). Forsberg and Saukkoriipi (2007) argue that measuring performance is not highlighted well in the lean concept but they agree that there are exceptions. They advocate for involvement of other parts of the organization in lean measurement, not just focusing on production at site. In their study on competitiveness of local construction contractors in Uganda, Ocen, *et al.,* (2011) observed that coordination gaps in the construction industry resulted in poor performance and slow growth and development. These gaps led to development of weak teams that could not tackle the needs of projects and contracts.

These observations suggest that for lean to be effectively implemented, processes in construction have to be considered not in part, but holistically. Variables that affect delivery of construction projects can be at any phase of the process, not necessarily during production on the site. Project environment factors affect the delivery process, even when they may be outside the control of project participants. This therefore

necessitates understanding project environment factors that potentially affect project performance. In this paper we focus on schedule performance.

Project Environment Factors and Schedule Performance

The project environment is the aggregate of surrounding things, conditions, or influences (Youker, 1992). Project environment factors may be internal or external. Internal environment factors are factors within the organization/company that determine the way the organization operates, such as organizational culture and leadership styles, which have an effect on performance and effectiveness (Alnaseri, *et al.,* 2013). External environment factors are those factors that are outside the organisation, about which management of the organisation has no control. (Kumaraswamy and Chan 1998; Gudiene, *et al.,* 2013). These factors provide unique challenges to projects. Saad and Chafi (2018) listed some challenges limiting project performance in the Moroccan construction industry, classifying them into; 1) external factors (e.g. price rigidity, low cash, foreign cash), and 2) internal factors (e.g. high expense, local sourcing and debt collection and unsatisfactory competitive environment). Fawcett and Cooper (2001) mention the fragmented and cyclic nature of the construction industry as a barrier to benchmarking, which is considered key in application of lean. Table 1 below provides a summary of these environment factors that affect project schedule performance.

Table 1: Environment factors affecting schedule performance in the construction industry

Category	Factors
Internal Factors	Communication, Collaboration and team work (Ocen *et al.,* 2011), Leader support and reward system (Polat and Adit, 2005), skills and active leadership (Fawcett and Cooper, 2011)
External Factors: Political	Safety, community perception (Ho and Pike, 1991)
External Factors: Economic	Accessibility of materials, finance, equipment, labour, degree of demand (Ho and Pike, 1991), economic growth, interest rates, exchange rates, inflation rates (Ocen, *et al.,* 2011).
External Factors: Technological	Locally made plant and equipment, magnitude of local material resources, level of utilization of local resources, skilled manpower resources (Kangari and Riggs 1989)

These factors present inherent risks that can interfere with the planned progress of the project, impacting performance, yet they remain largely unpredictable. They have to be taken into consideration and measures put in place to manage them during construction, to avoid delays and other hitches on the project. Having the project environment factors in mind, it is necessary for accurate forecasting of trends to be done during planning, in order for lean application to be a viable solution to delays caused by these factors. That way, alternative approaches to processes can be put in place for any eventualities that threaten project progress. That said, these environment factors are clearly context specific - and that is why an empirical study of the Ugandan context was warranted.

METHODS

Research Approach

The study adopted a mixed method approach (Denzin and Lincoln, 2005; Patton, 2005), studying Uganda's construction in its natural form; using questionnaires, semi structured interviews and participant observation. The approach was chosen because it generates rich, detailed data and provides context for the phenomena being studied, since phenomena can be viewed from different viewpoints. Moreover, findings would be validated by the different sources (Bailey-Beckett and Turner, 2001), thus minimizing the inadequacy of using a single research method and ensuring corroboration and clarification of results.

Identifying Project Environment Factors in Relation to Schedule Performance

Questionnaires were administered to contractors registered with Uganda National Association of Building and Civil Engineering Contractors (UNABCEC), a trade body for contractors in Uganda, in Class A and B categories. The classification criteria is based on number and contract sum of projects a company handles in a year, equipment capacity and human resource. Companies in A and B categories were chosen because they are believed to have the ability and financial strength to implement lean (Alinaitwe, 2009). Eighty contractors were registered in Class A and B categories at the time of data collection in March 2016. Sample selection was according to Amin (2005); at a significance level of 5%, the sample size was 67 contractors out of 80 companies in classes A and B. Interviews were also conducted to look out for participants' narratives about their experiences working on construction projects as far as project timelines were concerned. Respondents also provided information about project environment factors that affected their projects. The researcher also participated in one public construction project in Uganda, working for the Main Contractor. The processes of project delivery were observed, and compared with recommended best practice, as well as studying parameters within which the project was executed. Also considered were the organisational structure, available infrastructure and resource availability on the project, all which are factors that impact project schedule performance.

Identification of Lean Approaches

Past researchers have studied lean and its implementation to improve performance in the construction industry in many parts of the world. Successfully implemented lean approaches were identified through review of existing literature, which were further studied in context of Uganda's construction industry to find their applicability in Uganda. These factors were then matched with favourable project environment factors identified above, in order to isolate those that could contribute positively to schedule performance. This information was then used to argue for the need of a strategy towards improving schedule performance of construction projects with lean construction, cognizant of the project environment factors.

RESULTS AND DISCUSSION

General

Out of 67 questionnaires given to contractors, 63 were returned, making the response rate 94%. Site Engineers were the highest respondents of questionnaires (37%), followed by Architects (22%) and Foremen (20%). Other professions (project managers, surveyors, clerk of works, draughtsmen) were distributed over the

remaining 21%. Regarding experience in construction, 48% of respondents had less than 10 years' experience,46% had experience of 10 - 15 years, and the least number was those with over 15 years (6%) of experience. The project on which the researcher participated was a public hospital rehabilitation that started in November 2014, with an initial budget of $29 million, and two years' contract duration.

Despite contractual obligations to have organisation structures for construction projects, with specific qualifications and requirements for team leaders, respondents who led projects had different professional backgrounds, some of them less than desirable. For example, most contracts require that project managers should lead project teams, but from interviews, it was observed that some project managers did not have full presence on sites as per contractual obligations, while others did not have the requisite qualifications. This showed laxity in enforcing requirements to run construction projects and explains why there are many problems facing projects. Employees' experience plays an important role in running projects, because work tends to get done quicker and easier with more experience. It also influences decision making with more experienced managers taking quicker decisions that can save project time and being able to predict outcomes easily. From the findings, it is clear that some delays occur because participants lack adequate experience in construction processes. These findings agree with past research that the ratio of technical staff to non-technical staff is an internal factor which impacts technical capability and therefore productivity on a project (Ocen, *et al.,* 2011). Inexperienced project leaders are more likely to make mistakes that lead to reworks, take long to make decisions for fear of associated risks, all which are likely to lead to wastage of time, hence delays.

Project Environment Factors in Relation to Schedule Performance

A number of factors that affect project schedule performance were identified. Majority (70%) of the respondents said projects exceeded their original contract duration and faced problems of time overruns, giving top 3 reasons for delays as use of unprofessional contractors and managers (30%), delayed payment of contractors (26%) and design changes (20%). Material price fluctuations and unavailability of resources were also common factors said to affect project schedule performance. Through participant observation, the researcher observed the external and internal project environment factors which impacted the project which included: the organisation structure, communication channels, nature of meetings held and who participated in these meetings and adherence to the work program. Also studied were the procurement processes for materials; procedures for material requisitions and their delivery to the site. The project in which the researcher participated was a public project where client meetings were attended by major stakeholders; funders, ministry officials, the consultants and only the Project Manager from the Main Contractor's team. Actual versus planned durations were compared and, it was observed that, often, work did not go according to plan. There were delays in material and equipment deliveries and activities took longer than planned, affecting their successors. For example, imported materials like floor and wall tiles, vinyl flooring, ceiling tiles, electrical equipment, among others all did not arrive on time, which subsequently delayed related works. Reworks were many because of lack of coordination among subcontractors, and this inevitably affected the work program. Although the original contract duration was two years, an Extension of Time was granted three times; twice with costs and the third time without cost, bringing the project duration to 6 years; 3 times the original planned duration. This was majorly due to design changes. There were also many variations on the project, which showed

that the project scope was not well established at the time of commencement. The contract faced a cost overrun of $13 million, due to variations and scope increase on the project. Casual labour was affected too because the longer the project took, the less morale workers had, which affected productivity on the project. Lack of coordination among subcontractors, broken communication channels, and poor initial project planning, all impacted project schedule performance because the project deviated from the original plan and was difficult to get back on track.

Lean Approaches to Improve Schedule Performance

Whereas lean is a popular theory among researchers and scholars, as earlier discussed in literature, little is known about it in Uganda's construction industry, much less its application understood. For instance, many interview participants had varying interpretations of Lean, such as "the manufacture of parts that are later assembled", "team work in a construction project" and "minimizing wastage of resources on a construction site", among many uncoordinated interpretations. Some, however, had totally no idea regarding lean and how it applies in construction. However, the Lean tools identified in literature can be applicable, if tailored to project environmental factors in Uganda's Construction industry. With problems leading to poor schedule performance and low productivity on construction projects in Uganda in mind, lean tools identified to address these problems, cognizant of project environmental factors, were the last planner system, collaboration planning, value stream mapping and Just in Time. The last planner is a system used to prevent plan failure on projects through assignment level planning or look ahead scheduling. Collaborative planning improves communication and collaboration among participants to improve project delivery. A value stream map divides the process into smaller sub-processes, activities or tasks to clarify how the product flows between the activities. Just in time application in construction requires management and employee commitment to eliminating waste of any kind by adhering to schedules, clearly planning out tasks and ensuring ready supply of materials to ensure no time is wasted through waiting. It enables prompt delivery of materials, information and drawings to the point of usage.

These four tools identified above all require participants' total involvement in the process, for better coordination of activities. They call for prior planning before the project construction commences such that resources are received as and when they are required, unnecessary processes that waste time are removed, and follow ups are made daily, to ensure adherence to the program. Some practices (e.g. frequent meetings, proper communication channels, schedule updates) are often applied but participants have no idea that these are Lean practices, which perhaps justifies why these practices are not implemented as should be. For instance, most interview respondents noted that both consultants and contractors were highly involved in meetings but the other parties, such as the client and sub-contractors, attended on a less frequent basis.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

This research was conducted in response to the need for improved schedule performance on construction projects in Uganda. Both internal and external project environment factors that are critical for project schedule performance were identified. Lean construction was proposed as a modern method of construction that can improve schedule performance if properly implemented, that is, cognizant of the project environment factors. However, it was realised that participants are stuck to

old/traditional methods of delivering projects and are reluctant to change and adopt new management methods yet lean requires implementation of new tools and concepts to construction processes. It was also observed that the concept of lean is still novel in Uganda, and for the benefits of lean construction to manifest, industry participants should be willing to move away from what has been known to be the norm in project delivery and to try something new. Lean construction has not been widely applied in Uganda partly because it is not very clear what lean construction is and what the principles of its application are

This research suggests that understanding the environmental variables affecting construction projects makes it easier to implement lean holistically to improve performance. Construction projects in Uganda are micromanaged, and there are hierarchal boundaries established between participants on the same team. This directly affects communication among the team and the result of poor communication is seen through inconsistencies in the way projects are run. Traditional hierarchical structures curtail functional interface, which results into project schedule delays.

Recommendations

Now that we have identified the major causes of delays on projects and environmental factors affecting project schedules as well as the appropriate lean approaches to address them, a strategy for lean construction integration into construction projects should be developed. The strategy should be flexible to cater for uncertainties caused by project environment factors that are inevitable in the construction industry. In addition, the strategy should be codified into a lean construction application manual.

REFERENCES

Abd El-Razek, M E, Bassioni, H and Mobarak, A M (2008) Causes of delays in building construction projects in Egypt, *Journal of Construction Engineering and Management*, 134(**11**), 831-841.

Alinaitwe, H M (2009) Prioritizing Lean Construction Barriers in Uganda's Construction industry, *Journal of Construction in Developing Countries*, 14(**1**), 15 - 30.

Alinaitwe, H M, Mwakali, J and Hansson, B (2010) Assessing the degree of industrialization in construction - A case of Uganda, *Journal of Civil Engineering and Management*, 12, 221-229.

Alnasseri N, Osborne A and Steel G (2013) Organizational culture, leadership style and effectiveness: A case study of Middle Eastern construction clients. *In:* Smith, S D and Ahiaga-Dagbui, D D (Eds.), *Proceedings 29th Annual ARCOM Conference*, 2-4 September 2013, Reading, UK, Association of Researchers in Construction Management, 393-403.

Amin, M E (2005) *Social Science Research; Conception, Methodology and Analysis*. Makerere University, Kampala.

Aouad, G, Lee, A and Wu, S (2006) *Constructing the Future: Building Information Modelling*. London: Taylor and Francis.

Aziz, R F and Hafez, S M (2013) Applying lean thinking in construction and performance improvement, *Alexandria Engineering Journal*, 52(**4**), 679-695.

Babalola, O D, Ibem, E O and Ezema, I C (2018) Assessment of and adoption of lean practices in the Nigerian building industry, *International Journal of Civil Engineering and Technology*, 9(**13**), 1626-1640.

Ballard, G (2000) *The Last Planner System of Production Control*. School of Civil Engineering, Faculty of Engineering, the University of Birmingham.

Ballard, G and Howell, G (1998) Shielding Production: Essential step in production control, *Journal of Construction Management and Engineering*, 124(**1**), 11-17.

Bailey-Beckett, S and Turner, G (2001) *Triangulation: How and Why Triangulated Research Can Help Grow Market Share and Profitability*, Beckett Advisors Inc.

Denzin, N K and Lincoln, Y S (2005) Introduction, *In*: *The Discipline and Practice of Qualitative Research. the Sage Handbook of Qualitative Research 2nd Edition*. Thousand Oaks, CA: Sage.

Egan, J (1998) *Rethinking Construction*. London: Department of Environment, Transport and the Region.

Fawcett, S E and Cooper, M B (2001) Process integration for competitive success, benchmarking barriers and bridges, *Benchmarking*, 8(**5**), 396-412.

Forsberg, A and Saukkoriipi, L (2007) Measurement of Waste and Productivity in Relation to Lean Thinking, *In:* C L Pasquire and P Tzortzopoulos (Ed.), *Proceedings of 15th Annual Conference of the International Group for Lean Construction*, East Lansing, Michigan, 67-77.

Gamal, M S (2013) *Improving Project Performance Using Lean Construction in Egypt: A Proposed Framework*. The American University of Cairo, Egypt.

Ghenbasha, M, Omar, W, Sabki, M and Afizah, A (2016) Causes of construction delay in developing countries: A theoretical review, *In*: *The 1st International Conference on Invention and Design (ICID) 2016*.

Gudiene, N, Banaitis, A and Banaitiene, N (2013) Evaluation of critical success factors for construction projects - An empirical study in Lithuania, *International Journal of Strategic Property Managemen*t, 17(**1**),21-31.

Guo, H (2009) *Rethinking Construction Project Management Using the VP-Based Manufacturing Management Model*, PhD Thesis, The Hong Kong Polytechnic University, Hong Kong.

Ho, S S and Pike, R H (1992) The use of risk analysis techniques in capital investment appraisal, *In*: J Ansell, F Wharton (Eds.) *Risk Analysis Assessment and Management*. Hoboken, NJ: John Wiley and Sons, 71-94.

Kangari, R and Riggs, L S (1989) Construction risk assessment by linguistics, *IEEE Trans Engineering Management*, 362 126-131.

Koskela, L (1992) *Application of the New Production Theory to Construction*, CIFE Technical Report, Issue 72, Stanford University.

Koskela, L (2000) *An Exploration Towards a Production Theory and Its Application to Construction*. Technical Research Centre of Finland. Available from https://www.vtt.fi/inf/pdf/publications/2000/P408.pdf [Accessed 28/07/2019].

Koskela, L and Howell, G (2011) *Reforming Project Management: the Role of Planning, Execution*. University of Salford, UK

Kumaraswamy, M M and Chan D W (1998) Contributors to construction delays, *Construction Management and Economics*; 16(**1**), 17-29.

Latham, M (1994) *Constructing the Team*. London: HMSO.

Lee, C (2008) BIM: Changing the AEC Industry, *In*: *Project Management Institute Global Congress 2008*, Denver, Colorado, USA.

Luo, Y, David, R R and Michael, J H (2005) Lean principles for pre-fabrication in green design-build (GDB) projects, *In*: *13th International Group for Lean Construction Conference Proceedings*, International Group on Lean Construction, 539.

Muhwezi, L, Chamuriho, M and Lema N M (2013) Materials wastage estimations on building construction projects in Uganda, Caspian Journal of Applied Sciences Research, 2, 285-291.

Nordin, N and Deros, B (2017) Organizational change framework for lean manufacturing implementation, *International Journal of Supply Chain Management*, 6(**3**), 309-320.

Ocen, S J, Alinaitwe, H and Tindiwensi, D (2011) An analysis of the competitiveness of local construction contractors in Uganda, *In*: *Second International Conference on Advances in Engineering and Technolog*y, 346 - 352.

Ouwor, D O (2016) *Factors Influencing Completion of Construction Projects in Kenya: A Case of Government Buildings, Construction Projects in Nairobi County, Kenya*. Master's Thesis, University of Nairobi.

Patton, M Q (2005) *Qualitative Research*. Hoboken, NJ: John Wiley and Sons, Ltd.

Polat, G and Arditi, D (2005) The JIT materials management system in developing countries, *Construction Management and Economics*, 23 (**7**) 697-712.

Saad, M B and Chafi, A (2018) Empirical study of schedule delay in Moroccan construction projects, *International Journal of Construction Management*. Avaiable from https://doi.org/10.1080/15623599.2018.1484859 [Accessed 28/07/2019].

Sacks, R and Goldin, M (2007) Lean management model for construction of high-rise apartment buildings, *Journal of Construction Engineering and Management*, 133(**5**), 374-384.

Sarhan, S and Fox, A (2013) Barriers to implementing lean construction in the UK Construction industry, *The Built and Human Environment Review*, 6.

Ssemwogerere, K (2011) A case for acceleration rather than extension of time on construction projects in Uganda, *In*: *2nd International Conference on Construction and Project Management*, IACSIT Press, Singapore.

Womack, J P and Jones, D (2010) *Lean Thinking: Banish Waste and Create Wealth in Your Corporation*, New York: Free Press.

Youker, R (1992) Managing the international project environment, *International Journal of Project Management*, 10(**4**), 219-226.

THE INFLUENCE OF KEY PERFORMANCE INDICATORS ON RELATIONSHIP AND PERFORMANCE OF JOINT VENTURE CONSTRUCTION PROJECTS IN THE UK

Jon Lonsdale[1] and Catherine Lucas

Architecture and Built Environment, Faculty of Engineering and Environment, Sutherland Building, Northumbria University, Newcastle upon Tyne, NE1 8ST, UK

Joint ventures (JVs) are increasingly common within construction as companies seek to pool resources and expertise to broaden opportunities and mutually benefit from the arrangement, particularly for large-scale projects (LSPs). Whilst there are many benefits to joint ventures they are not without issue and in many cases result in dispute, often over the performance measurements used within the projects. A successful joint venture is one where parties share and understand the vision of the project. However, Key Performance Indicators (KPIs) are seldom discussed or completed collaboratively in joint ventures and may result in representing one-sided requirements. In theory, the evolving relationship between joint venture partners should lead to a refinement of KPIs along the project. However, the establishment of clear KPIs from the outset has the potential to reduce the number of disputes and provide the basis for a successful partnership. The aim of this paper is to critically evaluate the usage and influence of KPIs on joint venture projects within the United Kingdom (UK) and seek to determine factors that contribute to successful relationships. Data were collected by conducting in-depth, semi-structured interviews with purposefully selected members who had an average experience of over six years participating in joint venture projects within the UK. Findings show that KPIs are used mainly to reflect on individual businesses' performance rather than to appraise joint ventures. While there are limitations to KPIs this research also indicates that KPIs are used inappropriately at times leading to the misconceptions as to their use and may possibly cause tension between joint venture partners.

Keywords: disputes, joint venture, key performance indicators, large scale project

INTRODUCTION

A JV is a commercial business arrangement in which two or more separate parties come together to complete a specific task (JLT 2016). They are a well-established and commonplace arrangement within a range of industries worldwide and purposefully combine resources, competencies and skills for mutual benefit. Construction projects are primarily one-off endeavours, with many unique features such as long periods, complicated processes, significant financial outlay and dynamic organisational structures (Zou *et al.,* 2007). Thus, the majority of construction joint ventures (CJVs) are typically short-term or for one project (Badger *et al.,* 1993). The arrangement allows the partnership to compete for larger and more complex projects,

[1] jon.lonsdale@northumbria.ac.uk

Lonsdale, J and Lucas, C (2019) The Influence of Key Performance Indicators on Relationship and Performance of Joint Venture Construction Projects in the UK *In:* Gorse, C and Neilson, C J (Eds) *Proceedings of the 35th Annual ARCOM Conference,* 2-4 September 2019, Leeds, UK, Association of Researchers in Construction Management, 668-677.

and to enter niche markets previously outside their realm. In pooling resources, a JV reduces the burden for the participating firms and, if successful, can offer considerable rewards to all parties involved with an increased opportunity to foster long-term relationships on subsequent project ventures. Participating in a JV within the market is a very challenging task, however, and can often be highly complex. It requires developing a deep mutual understanding and strategy to enable success (Kale *et al.,* 2010) necessitating time and effort on the part of all involved. One of the most common reasons for disputes arising is said to be due to the management structure on a JV project (Ruggeri *et al.,* 2016). Problems could occur between the partners due to lack of trust and of strong effective leadership (Kale *et al.,* 2010), disputes potentially arising over the performance measurements used by the management of JVs (Greineder and Christie 2016).

LITERATURE REVIEW

Types of Joint Venture Arrangement

The nature of the arrangement will ultimately depend upon the extent to which each party are willing to integrate and may be formed in a variety of ways as each is modified to suit the specific conditions of the JV under consideration. At its most basic level, however, the decision is usually between an integrated or non-integrated JV. An integrated JV is where two or more entities form a separate vehicle, usually a limited company, to share profit and loss appropriate to their percentage contribution within the contract (JLT 2016). If two parties form the JV, as is often the case, then the contribution is usually divided equally. The integrated JV is commonly used for projects of an immense size where the task of apportioning the work is particularly difficult. This necessitates parties to carefully combine their resources and personnel in an agreed-upon manner, sharing both the risk and the rewards that result from it (Green 2017). Non-integrated JVs tend to be restricted 'arms-length' affairs. Each partner is allocated a range of work and is responsible for supplying resources in the agreed upon proportion as well as the profit and loss associated with it (Green 2017). This form is most commonly used where the work is easily divided into discrete sections between the JV partners and in some cases, may even have distinct roles. For example, one is responsible for producing the design, the other executing the construction works. In some instances, depending upon the complexity of the project, it may be appropriate that a combination JV (a mix of both integrated and non-integrated JVs) be formed. Each member is assigned a portion of the work for which they are solely responsible but also share a portion of the work with one or more of the JV partners. Each member is therefore responsible for both the profit and loss for the scope of works under their direct control and for the portion of the work which is shared. It should be noted that although the UK government backs collaboration and JVs, there is a thin line between collaboration and collusion, as stipulated by the competition laws which must be abided by rigorously. EU procurement laws must also be followed, therefore additional consideration is required when a JV forms as a single entity (Speyart *et al.,* 2018).

The Growth of Joint Ventures

Seemingly, there is an increasing trend in the UK to move away from traditional procurement methods towards the use of more collaborative methods such as JVs (Pinsent Masons 2017). This is particularly apparent of CJVs, which in the UK is evidently due to the rise of large-scale infrastructure projects (Bachelder 2017). These include the expansion of Heathrow Airport, road and rail programs as well as an

investment programme into the Northern Powerhouse. The most high-profile examples are seen in developments such as High Speed 2 (HS2), which has seen the formation of several JVs for numerous phases including the London terminus at Euston between Mace and Dragados. The £1.3bn contract has propelled them to the top of the BCLive league table for March 2019; this single contract placing them above Kier totalling 36 contracts worth just under £300m, over £1bn fewer. According to Halai (2018), large-scale commercial projects are undertaken through JVs, but the phased development of housing also lends itself well to the JV model and is likely to play a key role with the housing shortage issue. The number of companies seeking to take advantage of opportunities such as these is likely to further drive the initiation of project collaboration and specifically the creation of JVs. Paradoxically, in combining with competitors, a JV vehicle acts as a strategy for dealing with competitors. Rather than tendering for the same projects, companies can work together to benefit both themselves and the project. However, it is of paramount importance that the correct partner to ally with has been thought out clearly and full due diligence checks are carried out (Ruggeri *et al.,* 2016). Although potentially difficult to predict, the liquidation of Carillion left the remaining partners with increased workloads, a notable reduction in pooled resources and significant financial implications. In some instances, it was necessary to assume full responsibility, purchasing additional resources and employing former venture partner workers to ensure the continuity of service.

Forming a Joint Venture

Like any relationship, familiarity with the other companies' personalities and abilities is needed in order to gain inner trust (Adnan *et al.,* 2011). It is necessary to perform rigorous background checks, to distinguish the acceptable companies from those who are incompatible to enter a JV agreement. Selecting the right partner from the outset can make a critical difference, and if done correctly can dramatically reduce complexity and the potential for dispute. Bresnen and Marshall (2010) stress the need for the partners not to have conflicting interests regarding culture, business, management and goals and that all alliances, such as JVs, have the project's success as the overall target. Achieving success requires developing a deep mutual understanding and strategy implemented by the management (Kale *et al.,* 2010; Greineder and Christie 2016; Ruggeri *et al.,* 2016), and advantages significantly outweigh the risks providing the initial setup is correct (Breslin and Deung 2018). Project governance is vital and should be a formal structure; a JV board ought to be established to make sure decisions are met collectively and the JV has the autonomy to function on its own (Ruggeri *et al.,* 2016).

Joint Venture Challenges

Whilst there are many benefits to JVs they are not without issue. Precise figures are difficult to determine; however, it is estimated that at least 40% and up to 70% of all JVs result in failure (Farrell 2014). For CJVs specifically, it is estimated that one in five ends in dispute and that the duration of disputes were also on the rise (Arcadis 2017). As the complexity of working directly with another company to deliver a job is inevitable, each business unit operates in different manners and under different regulations to achieve their fundamental aims and objectives (Yuming 2014). This can create an environment where disputes and aggravation can be prevalent. According to Yuming (2014), companies have varying driving forces behind their business scopes to achieve a project's success. These issues cause an environment in

which companies must compromise to achieve a way of working which fits both parties. Lack of trust in the abilities of JV partners increases the hostility when trying to work in a unified environment (Breslin and Deung 2018).

Performance Measurements

Beamish (2010) states that for a JV to be successful both parties must discuss what performance measurements they will use in advance of the JV taking place. According to Robson (2004), KPIs are the UK's preferred type of performance measurement. As a staple of the construction industry for several years, they enable a company to monitor its realistic targets and goals, in an engaging way to achieve the fundamental objectives whilst obtaining continual improvements. BRE (2017) state that for best practice, KPIs should be developed jointly with those involved. They must also: Agree with the stakeholders involved within the project, must be relevant, measurable, and shared openly to achieve best practice and unify the JV. Within companies with the best practices, senior managers firmly believe that measurement and targets are essential to communicate their goals and aspirations and help to keep their employees continuously striving for improvement (Ruggeri *et al.,* 2016). Yeung *et al.,* (2009) suggest KPIs are a managerial issue whereas Yang *et al.,* (2010) have specified the need for performance measurements to be at project, organisational and stakeholder levels. For overall success, KPIs must be objective and subjective, as well as hard and soft (Gligorea 2017). Ozorhon *et al.,* (2008) suggest that the partner's overall satisfaction on JVs is one of the most frequently used subjective indicators.

The lack of managerial structure and performance indicators within JVs is a major problem (Roberts *et al.,* 2016). Assessing the KPIs means that the associated parties can have common aims and objectives to work towards giving the JV a strong foundation for success (Constructing Excellence 2017). Not only do KPIs allow performance to be tracked and measured, but they also can be used to penalise poor performance and reward good work. Jelinek and Pettit (2012), state the importance of defining soft KPIs such as information sharing, innovation, and speed of decision making in addition to developing hard KPIs around growth and profitability, conducting meetings to address challenges of working together and establishing protocols for managing differences. Ruggeri *et al.,* (2016) suggest the critical need to predefine performance measurements and state that by using them, even at the selection stage, will help focus the right partner with the right goals and rewards. KPIs should be viewed as a preventative measure; avoiding or reducing issues before they occur by adjusting practices accordingly. In JVs, performance measurements and KPIs are often not discussed or done in collaboration becoming one-sided requirements (Beamish 2010, Roberts *et al.,* 2016). Yeung *et al.,* (2009) indicate the need for research into the importance KPIs hold in setting benchmarks for JV success.

METHODOLOGY

This study adopts a purposive sampling technique to engage individuals with relevant experience in the UK construction sector and uses a qualitative data approach to provide insight into their experiences. The methodology is in line with the exploratory nature of the research to provide a further understanding of the research subject (Brinkmann 2008). The semi-structured interview process allowed a balance between the flexibility of an open-ended interview and a structured interview, and involved a set of questions developed in advance, and consistently administered to participants (Campion *et al.,* 1988). The interviews focused on a combination of questions related to JVs and KPIs, designed and ordered to lead from one to another,

to target broad, descriptive responses, enabling the respondents to provide as much focused information as possible. The questions were developed from a review of the literature, taking themes from within the UK and other countries, and refined following a pilot study conducted with a construction professional with experience of working with JV projects.

The sampling strategy involved five participants currently working at professional level within the UK construction sector. Participants were purposefully selected from organisations with multinational experience, providing a variety of services; however due to the sensitive nature of the research few participants were willing to openly discuss matters involving JVs. The study was therefore limited to professional roles including Quantity Surveyors, Project Managers, and Company Directors with an average experience of over six years of working with JV projects and KPIs. Ethical guidelines were followed whereby each participant was informed of the nature of the research, its purpose, and what the resultant data will be used for (Naoum 2007). Informed consent of the participants was obtained, and anonymity and confidentiality were assured. In addition, the original recordings and transcript files were safeguarded by password protection and securely stored with restricted access.

The interview contained questions on individual demographic and career details, together with a set of 13 in-depth questions focused on the advantages and disadvantages of entering a JV partnership, together with questions focussed on the use of KPIs specifically on JVs. The participants were requested to respond to questions such as “how could partnerships be improved?”, and “how could KPIs used in JVs help achieve success?”. The participants were interviewed individually, for a duration of between 45 and 60 minutes, using either a face-to-face or a telecommunications application (Skype) method, depending upon their location or availability. The open-ended nature of the questions enabling the participants to fully express their experiences on the research subject. The interviews were digitally recorded to ensure that all information was captured, and verbatim transcriptions were produced enabling thematic analysis to be conducted, described by Braun and Clarke (2006) as "a method for identifying, analysing and reporting patterns (themes) within data". This was achieved in part by coding the transcripts, then gathering and collating the different pieces of related information to systematically identify themes within the data for analysis, an approach recognised by Agapiou (2002) as relevant to construction management research.

FINDINGS AND DISCUSSION

The findings from the semi-structured interviews were derived from a thematic analysis of the interview transcripts. The analysis revealed themes within the data that were discussed in relation to the factors that contribute to a successful relationship between JV partners, and the influence of KPIs on JVs.

Factors that Contribute to a Successful Relationship between Partners

A common consensus throughout the interviews was the vital role communication plays within JVs. However, although it was clear from the transcript data that participants were aware of the need to communicate effectively, they reported experience of resistance to do so, mainly due to organisational, cultural or language differences, which was expressed frustratingly by one participant as “they just shout, that’s their way”. Although ‘working in a silo’ is a major risk to organisations, and a collaborative approach is required for JVs, participants’ responses indicated that it was

not working, and it was expressed succinctly by one participant as "they excluded us from their operations". The participants agreed with previous research of Zhang, Wong and Chen (2010) that a clear communication strategy needs to be in place before the work starts to prevent disputes negatively impacting on productivity and relationships. Two of the more experienced participants also emphasised the need for a mutual understanding of abilities and expertise, which confirmed the findings of Yuming (2014), in terms of the need for trust and acceptance between the partners. Participants also agreed on the benefits of combining and unitising technology within organisations, thereby improving skill sets and capabilities of individuals. There was a fundamental tension between the resources required for day to day operational activities and long-term strategic goals.

The spreading of risk was identified as a key benefit, all participants acknowledge that entering a JV does pose risk and agreed that if the risk was properly considered it can be shared. The participants with the most experience with working with JVs made the point that although risk sharing is an advantage, due diligence tests are essential to minimise the risk. This premise agreed with Ruggeri *et al.,* (2016), who stated that due diligence was carried out to make sure the selected partner is the correct one. Some participants agreed that a JV was a way of entering into new markets, and it was emphasised by two participants that it was a means of taking advantage of organisations who have specific skills and expertise.

A main advantage of a JV identified by all participants was the sharing of expertise and skills. They emphasised that combining the correct expertise and skills was needed to execute elements of the works a single organisation would not be able to do on their own. Responses from all participants agreed that organisations operate with different aims and objectives and that working with another organisation can be difficult, as it may be hard to find a balance. This agrees with the research of Bing *et al.,* (1999) who acknowledged that companies operate to achieve their own aims and objectives in different ways. For the relationship to remain strong throughout a JV, the participants agreed goals must be set at the start of a project. A conscious effort should therefore be made to select common goals which promote trust and collaboration between all partners.

Participants placed high importance that the management team must be collaboratively set up at the start of the venture, and not "pulling in different directions" affecting decision-making and having the potential for unnecessary delays and additional costs. It was emphasised by four of the participants that avoiding conflicting interests is difficult, confirming the research of Bresnen and Marshall (2010). Problems associated with different organisational reporting styles were identified by some participants as a disadvantage to JVs. The lack of a unified approach or the need for an organisation to adopt an unfamiliar style, has the effect of potentially slowing down the venture and clear guidelines need to be put in place as to which reporting style the venture will follow. All participants agreed that personality differences had the potential to be problematic, with a participant amplifying that if mindsets are adversarial "they just won't speak to you" and ways of working have to be gauged, if to be successful. This is supported in the findings of Bird and Mendenhall (2016), who explain that because of differing cultures, everyone operates in different ways. Appreciating differences and using those to strengthen the partnership would ideally be useful for JVs.

All participants discussed the importance of learning in order to improve the success of a JV, and whilst learning can take place over the course of a JV, a theme from the data was that parties who have previously been involved in successful JVs can understand mindsets and attitudes, as they are more open to learning about different ways of procedure. For those involved in problematic JVs the opposite may be true in that they carry adversarial baggage. The participants all agreed that in order for a culture of working positively together to be instilled, it has to be present from the start of the venture, and it was suggested that this could be started by operating under the same brand name. One participant suggested using the same JV logo on all clothing, signage, advertising etc. to ensure the message that it was operating as one organisation was firmly embedded.

The Use of Key Performance Indicators on Joint Venture Projects

The views expressed by participants generally supported previous research by Constructing Excellence (2017), in that KPIs were set at the forefront of a changed focus within the construction industry, and provided the benefits of monitoring targets, achieving goals and obtaining continual improvements. However, some conflicting views were expressed with regard to the effective use of KPIs within JVs. It was acknowledged that KPIs were useful in JVs, provided stakeholders developed them jointly, with a shared vision and that they were relevant and beneficial to the project. The findings agreed with Beamish (2010), and Roberts *et al.,* (2016) that this was often not the case, and KPIs were used mainly to reflect on individual businesses' performance, representing a one-sided approach, and not effective as indicators within a JV. It was evident from the data that predefined performance measurements were sometimes not available at the selection stage of a project, and that organisations were not focussed on common goals, resulting in KPIs not being realised. There was some recognition of the use of 'soft' performance indicators such as the effective sharing of information and management decision-making as identified by Jelinek and Pettit (2012), however, they were strongly related to individual organisations and not regarded as effective within joint organisations, expressed as "it is the way we do things around here", further leading to a one-sided culture. Participants stated that they could see the potential of KPIs within JVs; however, they explained that in their experience they were not used appropriately and were viewed as being more of a schedule to hit, or an incentive to speed up work, which could drive a company "to cut corners". It was also stated that KPIs were incentives to reward positive performances, "formulas to get paid", and were "not used in a proper way". It was stated by one seemingly confused participant that there were "no KPIs on JVs, because the parties involved were equal partners", and that they were only "included within the main contract".

Other views expressed referred to organisations looking at 'accreditations' rather than 'benchmarking', emphasising that organisations are not currently looking to see how successful companies are at hitting goals, but are focusing more on achieving awards and accreditations. Some participants expressed their dislike of KPIs stating that they would need to be "fully compliant with the contract", whilst others stated that there are "other measures to make JVs work"; however, did not elaborate on what the measures could be. Participants recognised that there are benefits in using KPIs; however, in their experience, they were not used effectively, and often resulted in dispute, generally over the performance measurements used within the projects. It was also stated by the participants that in their experience KPIs caused conflict between individual organisations personnel, resulting in a culture of blame increasing

divergence of the JV partnership. Importance of performance measurement after a project was complete was acknowledged; however, not all participants agreed that there should be a joint measurement and questioned the effectiveness of using another organisations data with their JV business partners. It was stated that there was a lack of interest in the data produced by other organisations, and that organisations were generally unwilling to be open and share information. It was stated that JVs were normally one-off endeavours, so they could not be used to improve upon, which was the view of Hung *et al.,* (2002) who stated that JVs have limited life spans. However, this view was not supported by Toor and Ogunlana (2010) who see the potential of KPIs as a performance measurement instrument in order to benefit future JVs.

CONCLUSIONS

As the usage of JVs is set to increase then it is of paramount importance that they are established appropriately to avoid resultant disputes and encourage collaborative working for building competitive advantage. The research shows a resistance to communicate between partner organisations at operational level due to organisational, personality or cultural differences is one of the main problems, largely due to the management team not being collaboratively set up at the start of the venture. The importance of using KPIs to measure performance over the JV rather than for the individual organisations is clear within the literature. However, the findings show that KPIs are used mainly to reflect on individual businesses' performance rather than to appraise JVs and encourage potential of partners. Some venture partners have a lack of interest in the data produced by partner organisations, with an unwillingness to be open and share the information. There is also evidence from the research that the need for a mutual understanding of abilities and expertise within a JV is not apparent. The research shows that KPIs caused tension and conflict between JV partners, resulting in mistrust and a culture of blame. It is clear that although KPIs are used within CJVs they are not being developed jointly or used effectively. The evolving relationship between JV partners in the construction industry should lead to a refinement in the use of KPIs, which would help to alleviate the issues and problems highlighted within this research.

REFERENCES

Arcadis (2017) *Global Construction Dispute Report*. Available from https://www.arcadis.com/media/3/E/7/%7B3E7BDCDC-0434-4237-924F-739240965A90%7DGlobal%20Construction%20Disputes%20Report%202016.pdf [Accessed 09/01/2019].

Adnan, H Chong, H Y and Morledge, R (2011) Success criteria for international joint ventures: The experience of Malaysian contractors in the Middle East, *African Journal of Business Management*, 5(**13**), 5254-5260.

Agapiou, A (2002) Perceptions of gender roles and attitudes toward work among male and female operatives in the Scottish construction industry, *Construction Management and Economics*, 20(**8**), 697-705.

Badger, W W, Mulligan, D, Carter, I I J P, Gay, S W, Held, M S and Markham, C S (1993), *Alliances in International Construction a Report to the Construction Industry Institute*, The University of Texas, Austin, USA.

Bachelder, D (2017) *Owners Turn to PPPs, JVS and Alternative Delivery Methods, Construction Management: News, Resources, Best Practices*. Available from https://www.aconex.com/blogs/2016/01/ppp-jv-project-delivery-methods.html [Accessed 07/01/ 2019].

Beamish, P (2010) *The International Joint Venture: A Discussion with Professor Paul W Beamish*, Ivey Business Journal.

Bing, L, Tiong, R L K, Fan, W W and Chew, D A (1999) Risk management in international construction joint ventures*, Journal of Construction Engineering and Management*, 125(**4**), 277-84.

Braun, V and Clarke, V (2006) Using thematic analysis in psychology, *Qualitative Research in Psychology*, 3(**2**), 77-101.

BRE (2017) Key performance indicators for the construction industry. Available from https://www.bregroup.com/a-z/key-performance-indicators-for-the-construction-industry/ [Accessed 04/01/2019]

Bresnan, M and Marshall, N (2010) Partnering in construction: A critical review of issues, problems and dilemmas, *Construction Management and Economics*, 18(**2**), 229-237.

Breslin, M and Deung, J (2018) *Joint Ventures: What Are the Risks and How Do You Avoid Them*? Construction News. Available from https://www.constructionnews.co.uk/archive/joint-ventures-what-are-the-risks-and-how-do-you-avoid-them-27-02-2018/?search=https%3a%2f%2fwww.constructionnews.co.uk%2fsearcharticles%3fqsearch%3d1%26keywords%3djoint+ventures [Accessed 28th November 2018]

Brinkmann, S (2008) Interviewing, *In:* L Given (Ed*.) the SAGE Encyclopaedia of Qualitative Research Methods*. California: SAGE Publications, 471-473.

Campion, M A, Pursell, E D, Brown, B K (1988) Structured interviewing: Raising the psychometric properties of the employment interview, *Personnel Psychology*, 41, 25-42.

Constructing Excellence (2017) *KPIs and Benchmarking*, Available from http://constructingexcellence.org.uk/KPIs-and-benchmarking [Accessed 20/12/2018].

Farrell, P E (2014) *Partnerships: the 7 Deadly Sins of Joint Ventures*, https://www.entrepreneur.com/article/236987 [Accessed 17/12/2018]

Gligorea, R (2017) *Building Performance: KPIs Used in the Construction Industry*, KPI Institute, Available from http://www.performancemagazine.org/performance-KPIs-construction-industry/ [Accessed 17/12/2018]

Green, C (2017) Balancing Act, *RICS Construction Journal*, (April/May 2017), 1-3.

Greineder, D and Christie, K (2016) GAR Chapter: Joint Venture Disputes, Available from http://globalarbitrationreview.com/chapter/1036938/joint-venture-disputes [Accessed 17th December 2018]

Halai, M (2018) *Greater Than the Sum of Its Parts - Are Joint Ventures the Future of the UK's Housing Delivery*? Building, Available from https://www.building.co.uk/communities/greater-than-the-sum-of-its-parts-are-joint-ventures-the-future-of-the-uks-housing-delivery/5092403.article [Accessed 4th January 2019]

Hung, A L W, Naidu, G M Cavusgil, S T and Yam, R C (2002) An exploratory study of project based international joint ventures, *International Business Review*, 11(**5**), 505-522.

Jelinek, M and Pettit, J (2012) *The Joint Venture (JV) Handbook*, SSRN Electronic Journal.

JLT (2016) *Joint Ventures Insurance Considerations: Key Insurance Issues for Contractors and Service Providers*. London: JLT Specialty Limited, 3-7.

Kale, V V, Patil, S S, Hiravennavar, A R, Kamane, S K (2010) Joint venture in construction industry, *Journal of Mechanical and Civil Engineering*, ISSN: 2278-1684PP, 60-65.

Naoum, S G (2007) *Dissertation Research and Writing for Construction Students 2nd Edition*. Oxford: Butterworth-Heinemann.

Ozorhon, B, Arditi, D, Dikmen, I and Birgonul, M (2008) Implications of culture in the performance of international construction joint ventures, *Journal of Construction Engineering and Management*, 134(**5**), 361-370.

Pinsent Masons (2017) *Collaborative Construction 2 'Now or Never?*' Pinsent Masons, 10-17.

Roberts, M, Blundell, N, Dartnell R and Poynter-Brown R (2016) *Collaborative Construction: More Myth Than Reality?* Pinsent Masons 5-8.

Robson, I (2004) From process measurement to performance improvement, *Business Process Management Journal*, 10(**5**), 510-521.

Ruggeri, C, Armstrong, M, Gala, S and Fennessey, L (2016) *Joint Venture and Alternative Structure Transactions: Getting Them Right from the Start*, Deloitte Development LLC, 4-12.

Speyart, H, Meijenfeldt, M and NautaDutilh, N (2017) *EU Competition Law: Treatment of Joint Ventures*, Joint Ventures Law Global Guide.

Toor, S and Ogunlana, S (2010) Beyond the 'iron triangle': Stakeholder perception of key performance indicators (KPIs) for large-scale public sector development projects, *International Journal of Project Management*, 28(**3**), 228-236.

Yang, H, Yeung J F Y, Chan, A P C, Chiang Y H and Chan DWM (2010) A Critical review of performance measurement in construction, *Journal of Facilities Management*, 8(**4**), 269-284.

Yeung, J F Y, Chan, A P C and Chan, D W M (2009) Developing a performance index for relationship-based construction projects in Australia: Delphi study, *Journal of Management in Engineering*, 25(**2**), 59-68.

Yuming, H (2014) *An Empirical Study of Partners' Collaboration in Construction Joint Ventures (CJV) Projects and Its Impacts on Project Performance in Hong Kong*. PhD Thesis, Hong Kong Polytechnic University.

Zhang, L, Wong, W and Chen, P (2010) Critical factors influencing learning effectiveness in international construction joint ventures, *International Journal of Construction Management*, 10(**1**), 87-100.

Zou, PX W, Zhang, G and Wang, J (2007) Understanding the key risks in construction project, *International Journal of Project Management*, 25, 601-614.

PROJECT PLANNING

ASSESSMENT OF CRITICALITY OF MATERIALS IN A CONSTRUCTION PROJECT

Santu Kar[1] and Kumar Neeraj Jha

Department of Civil Engineering, Indian Institute of Technology Delhi, New Delhi, 110016, India

Material management is a key process for the success of a construction project. Typically, in a construction project, material accounts for 50-60% of the total project cost. Non-availability of material when required, potentially impact a construction project causing time overrun, cost overrun, and loss of productivity. Due to the complex nature of construction projects, it is difficult to measure the impact of non-availability of materials. It is essential to prioritise materials for procurement based on the impact of their non-availability, especially in the budget constraint situation. However, in practice criticality of materials in procurement has not been considered and also very few studies have been reported in this area. We propose, the total criticality (TC) of material for prioritisation of materials for procurement in budget constraint situation and as a measure of the impact of non-availability of materials. The TC of materials has been determined based on material criticality (MC) and activity criticality (AC). The AC has been obtained based on the float available for the activity. The MC has been determined using an integrated ANP-TOPSIS (analytic network process and technique for order preference by similarity to an ideal solution) approach which is a novel approach. This approach is employed with the additional criteria of MC such as environmental implication and volatility in price of materials along with the other reported criteria in literature such as percentage contribution, flexibility, lead time, customer's specificity, and buyer's dependence on suppliers. The ANP has been employed for determining the weight of the criteria by considering their interdependencies and pairwise comparison as obtained based on a questionnaire survey within a group of experts while for the TOPSIS, inputs from an institutional building project have been utilised. The reported study will help in timely and budgeted completion of construction projects.

Keywords: ANP, criticality, material management, prioritisation, TOPSIS

INTRODUCTION

The construction industry is a fast-growing sector, and its contribution to the global economy will increase to about 15% of the global GDP by 2020 (Schilling, 2013). The construction spending of the global market is expected to reach USD 14 trillion in 2025 (Statista, 2017). Countries likely to undergo substantial growth include China, India, Russia, Brazil, Poland, and the US. The growth of the construction industry leads to large consumption of materials in construction projects. Moreover, materials account for 50-60% of the total project cost of a construction project and influence 80% of the construction schedule (Caldas *et al.,* 2014). Hence, greater importance is required to be given to effectively managing the materials. Typically, a limited budget is allocated for procurement of materials for a certain period in a construction

[1] santu.iitd.11@gmail.com

Kar, S and Jha, K N (2019) Assessment of Criticality of Materials in a Construction Project *In:* Gorse, C and Neilson, C J (Eds) *Proceedings of the 35th Annual ARCOM Conference,* 2-4 September 2019, Leeds, UK, Association of Researchers in Construction Management, 679-688.

project, which restricts procurement of all materials at once. Project network characteristic needs to be considered for procurement of materials. Besides, managers desire to store materials which have other important criteria such as high volatility in price, high percentage contribution, long lead time, more buyer dependency, etc. Therefore, materials need to be prioritised for procurement to avail the right materials at the right time in construction projects, especially in a budget constraint situation (Dixit *et al.,* 2013).

Non-availability of materials when required, incur a penalty in the form of time overrun, cost overrun, and loss of productivity (Koushki and Kartam, 2004). The penalty can be minimised or avoided if materials are prioritised for procurement considering their criticality values. Criticality of a material indicates the relative quantitative measure of the penalty due to their non-availability. Although it is essential to determine the criticality of materials and to prioritise them for procurement, very few studies are reported in this area in literature. Also, no prior study has been reported in the literature demonstrating the methodology for determining the criticality of construction materials that have both multiple criteria and interdependence property.

In this study, the above need is addressed by assessing total criticality (TC) of materials based on material criticality (MC) and activity criticality (AC). MC is the criticality of material concerning the activity whereas, TC is the criticality of materials concerning the overall project as it integrates the project network by assessing AC. The MC values of materials are calculated based on some criteria using ANP (analytic network process) - TOPSIS (technique of order preference by similarity to ideal solution) method. Specifically, we demonstrate how an integrated ANP-TOPSIS method can be used for determining MC values by considering interdependence among criteria. An institutional building project is considered as a case project for calculating TC values of materials. Higher TC value indicates the higher penalty due to the non-availability of materials. Greater follow-up and coordination with suppliers need to be adopted for highly critical materials. Procurement of materials by prioritising them based on the TC values can reduce the penalty incurred due to the non-availability of materials and will assist in timely and budgeted completion of the construction projects. Furthermore, TC values can be adopted as the shortage cost coefficients in the inventory model as it incorporates both material perspective and project perspective. This study contributes to the body of knowledge by integrating material management with the construction schedule and demonstrating a systematic approach for prioritisations of materials through the assessment of their criticality values.

LITERATURE REVIEW

The penalty incurred due to non-availability of materials were described by Huiskonen (2001) defining two dimensions: (1) process criticality which is related to the penalties due to loss of work and (2) control criticality which is related to the supply uncertainty of items. Dixit *et al.,* (2013) addressed the integration of material management with project management. The researchers adopted the criteria such as percentage contribution, flexibility, buyer's dependence, customer specificity, and lead time to determine criticality values of materials. They adopted fuzzy inference system (FIS) in the study. Overall criticality (OC) of material was determined based on material criticality (MC) and activity criticality (AC) values. OC was treated as the prioritisation measure of materials. However, they did not consider the

interdependencies among criteria and the study was in the context of manufacturing of complex products. Criticality of materials in infrastructure projects was introduced by Purnell *et al.,* (2013). They described that disruption of the supply of critical materials could be affected by geological reserves, geopolitics, and increasing demand. However, in this study, the criticality of materials was demonstrated in the context of raw materials and project network characteristic was not considered. Lapko *et al.,* (2016) described the materials that are said to be critical due to their high supply constraints and high economic importance.

The above studies did not incorporate sustainability aspects for the assessment of material criticality. Hallstedt and Isaksson (2017) explained that sustainability aspects had an impact on criticality and introduced it for assessing the criticality of alloy materials. Knoeri *et al.,* (2013) described the importance of environmental implication for assessing the criticality of raw materials. Researchers mentioned that environmental implication could restrict the material supply. Glöser *et al.,* (2015) addressed the criticality of raw materials considering supply risk, vulnerability, and environmental implication. Lloyd *et al.,* (2012) considered that environmental limitation would cause stricter legislation and hence will restrict the supply of materials. Environmental aspects of criticality have been considered by researchers in many terms such as environmental restrictions, environmental performance, environmental impacts, and environmental implications (Nieto *et al.,* 2013; Knoeri *et al.,* 2013; Ku *et al.,* 2018). However, for this research, environmental implication will be used as the criteria from sustainable aspects to determine the MC values.

A comprehensive literature review has revealed that no prior study is reported for assessment of criticality of construction materials. Although it is important to incorporate project network characteristic for assessing criticality, very few studies considered this. Also, interdependencies among criteria are not considered while determining criticality. Therefore, it is essential to assess the criticality of construction materials considering sustainable aspects, interdependencies among criteria, and incorporating project network characteristic.

RESEARCH METHODOLOGY

The research was carried out focusing on the construction industry. The criteria governing the MC values were identified from the literature. The criteria were reviewed by a group of experts who have extensive experience and knowledge of material management in construction. Twelve professionals from the leading construction companies, working as project manager, planning engineers, store engineers, and procurement engineers were selected as experts. The professionals have a work experience of ten to thirty-five years in material management. A questionnaire survey was conducted among the group of experts to identify the interrelationship between the criteria. The experts were asked to rate the effect of one criterion on to the other criteria on a Likert scale of 1-5. Here, 1 represents ‘very less effect’ and 5 represents ‘very high effect.’ The mean values of the responses were calculated and based on it the interrelationship between criteria were drawn. Another questionnaire survey was carried out to obtain the relative importance of criteria by comparing them pairwise considering their interrelationships. The ratings were obtained on 1 - 9 scale. Here, 1 represents ‘equal importance,’ and 9 represents ‘extreme importance’ when comparing one criterion over another (Saaty, 1990). Subsequently, using the ANP technique in the Super Decisions 2.10 (SD) software, the weights of the criteria were determined. Consistencies of the collected responses

were also computed using the software. The ANP technique was adopted for obtaining the precise weights of criteria as it considers collective effort from a group of experts, and gives a better structure for decision support, and also considers interdependencies among the criteria.

Further, the MC values of materials in an institutional building project was calculated using the TOPSIS method considering the weights of the criteria and input for the specific materials given by the three project professionals who are involved in the material management process in the project. Input on percentage contribution (PC) and lead time (LT) was captured in percentage and days respectively. Flexibility (FE), customers' specificity (CS), and buyer's dependence on suppliers (BD) were taken as input on a 1-5 scale where 1 represents very low, and 5 represents very high. Environmental implication (EI) was taken as tons of carbon dioxide emission for production of 1 ton of material and volatility in price of material (VP) as the ratio of maximum price to minimum price for the 5 years. The criteria of MC include both positive and negative criteria. The TOPSIS method was adopted because it can incorporate both positive and negative criteria in the analysis. Positive criteria and negative criteria are the criteria which have a direct relationship and inverse relationship with MC respectively. The MC value increases with the increase of the positive criteria value of the material whereas, the MC value decreases with the increase of the negative criteria value of the material. The, AC values of materials were obtained based on the float available for the activities to which they are involved according to the construction schedule of the institutional building project. Further, TC values of materials were determined by combining MC values with AC values of respective materials.

Determination of material criticality

Criteria of material criticality

To determine the material criticality (MC), the first step is to identify the criteria that influence the MC. The six criteria of MC were identified after reviewing the literature. The criteria were reviewed by the group of experts and an additional criterion termed 'volatility in price of materials' was identified from the discussion with experts. The criteria with their description and relationship with the MC are provided in Table 1.

Interrelationship between criteria

To determine the interrelationship among criteria forming a network structure is the most important step of ANP. For this, we collected responses from a group of experts based on a questionnaire survey. The effect of one criterion to others was captured on a 1-5 scale and the mean value of the responses was calculated. It was considered that a particular criterion affects another criterion if the mean value obtained was more than 3 (Ahuja *et al.,* 2009). For example, the mean value of the effect of percentage contribution (PC) on flexibility (FE) was obtained as 3.8. However, the mean value of the effect of FE on PC was 2.6. Therefore, PC affects FE, but FE does not affect PC. The resulting network structure is shown in Figure 1.

From Figure 1, it can be seen that environmental implication (EI) has no relationship with other criteria of MC, because EI does not affect any criterion and no criterion affects EI. However, other criteria are interrelated as shown in Figure 1.

Determination of the weight of criteria using ANP method

Another questionnaire survey was carried out to obtain the relative importance of criteria by comparing them pairwise. The questionnaire was developed based on the

interrelationship among criteria. In the first section of the questionnaire, the experts were asked to evaluate the criteria with respect to MC without assuming their interdependencies. To compare the criteria pairwise, it was asked which criterion is more important and how much more important on a 1-9 scale. Pairwise comparison matrices of the individual responses were developed. Consistency ratios (CR) of the individual responses were calculated using the SD software. To combine the individual responses, an overall pairwise comparison matrix was determined using the Eq. (1) as reported by Wakchaure and Jha (2012).

Table 1: Criteria and their relationship with MC

S. N	Criteria	Description	Relationship with the material criticality (MC)
1	Percentage contribution (PC)	It is the percentage contribution of material for completion of the activity.	A material with higher PC leads to higher penalty due to its non-availability. Thus, PC is directly related to MC.
2	Flexibility (FE)	It is the likelihood to carry out an activity adopting other ways or using other alternative materials, in case the material is not available.	A material with lower FE will cause higher penalty as the possibility to carry out the associated activity is lesser. Thus, FE is inversely related to MC.
3	Lead time (LT)	It is the time to deliver a material to the construction site after placing the order to the supplier.	A material with higher LT has high supply risk and requires more follow-ups, causing higher expediting cost. Thus, LT is directly related to MC.
4	Customers' specificity (CS)	It is the uniqueness of the material which demands technical expertise.	A specialised supplier is required for a material with higher CS value. Higher level of communication is required for its procurement. Therefore, CS is directly related to MC.
5	Buyer's dependence on suppliers (BD)	It is the degree to which the buyer needs a particular supplier to procure the material.	BD is directly related to MC.
6	Environmental implication (EI)	It is the measure of environmental performance associated with material production/manufacturing.	If the emission of carbon dioxide is high, then EI is high. This may increase the supply risk of material due to a stricter legislation policy decision. Therefore, EI is directly related to MC.
7	Volatility in price of material (VP)	It is the degree of variation of material price over time.	If the VP is high, the risk in purchasing the materials are high as the price of materials may increase to a high amount. Therefore, VP is directly related to MC.

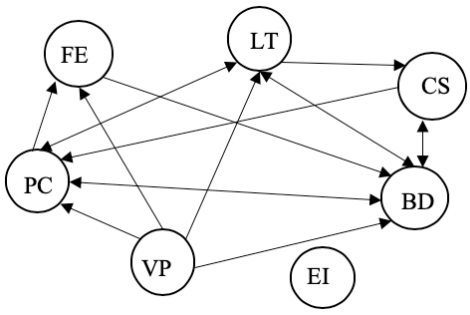


Figure 1. Interrelationship between criteria

For combining, the responses were weighted based on their consistencies on a prorate basis (see Eq. 1). For example, a response with a higher consistency was given a higher weight in comparison to the response with a lower consistency.

$$y_{ij} = [x_{1ij}^{w_1} \times x_{2ij}^{w_2} \times .... \times x_{nij}^{w_n}]^{\frac{1}{w_1+w_2+\cdots+w_n}} \quad (1)$$

Here, y_{ij} is the cell entry of the combined pairwise comparison matrix and x_{nij} is the cell entry of the pairwise comparison matrix of the nth respondent. w_n is the weight

assigned to the nth respondent which is equal to (1 - CRn) and CRn is the consistency ratio for the nth respondent. The weight of the criteria (w_1) without considering interdependencies was determined based on the combined pairwise comparison matrix of criteria with respect to MC as provided in Table 2. The CR value of the combined matrix was obtained as 0.036 which is less than 0.1 and assures the consistency of the responses

Table 2: Weight of the criteria without considering its interdependencies

	PC	FE	LT	CS	BD	EI	VP
Weight (w_1)	0.122	0.110	0.190	0.179	0.095	0.090	0.214

In the second section of the questionnaire, the experts were asked to evaluate the criteria considering their interrelationship. For example, LT, CS, BD, and VP affect PC as shown in Figure 1. Therefore, it was asked to evaluate LT, CS, BD, and VP by comparing them pairwise with respect to PC. Similarly, it was asked to evaluate criteria with respect to FE, LT, CS, and BD. However, no criteria affect EI and VP. Pairwise comparison matrices were developed based on the individual responses and were combined using Eq. (1). The priority vectors of the matrices were obtained. Combining the priority vectors, the interdependence matrix of criteria (w_2) was determined as shown in Table 3. Zero was assigned to the eigenvector of criteria which are independent. The CR values of the matrices were obtained as less than 0.1 that confirm the consistency of the responses.

Table 3: Interdependence matrix of criteria

w_2	PC	FE	LT	CS	BD	EI	VP
PC	0.500	0.263	0.166	0.353	0.100	0.000	0.000
FE	0.000	0.500	0.000	0.000	0.032	0.000	0.000
LT	0.158	0.000	0.500	0.000	0.112	0.000	0.000
CS	0.108	0.000	0.000	0.500	0.099	0.000	0.000
BD	0.092	0.000	0.095	0.000	0.500	0.000	0.000
EI	0.000	0.000	0.000	0.000	0.000	1.000	0.000
VP	0.142	0.237	0.239	0.147	0.157	0.000	1.000

By synthesizing the above results weight of the criteria (w_3) with interdependencies were obtained as given in Table 4 using Eq. (2). Considering interdependencies, the weight of the criteria of MC has changed significantly which reveals the novelty of the ANP method.

$$w_3 = w_2 \times w_1 \quad (2)$$

Table 4: Weight of the criteria considering its interdependencies

	PC	FE	LT	CS	BD	EI	VP
Weight (w_3)	0.194	0.058	0.125	0.112	0.077	0.090	0.344

Determination of MC values using TOPSIS method

TOPSIS technique determines the preference of alternatives based on the distance from the positive ideal solution and the negative ideal solution. The best alternative

has the shortest distance from the positive ideal solution and farthest from the negative ideal solution. To calculate MC values adopting TOPSIS method, a total of 5 materials (representing alternatives) required in the building project were considered. The project professionals were asked to evaluate materials under each individual criterion. A decision matrix was established calculating the geometric mean of the individual responses. A normalised decision matrix was developed using Eq. (3). Further, a weighted normalised decision matrix was developed using Eq. (4) as shown in Table 5.

$$r_{ij} = x_{ij} / \sqrt{\sum_{i=1}^{5} (x_{ij})^2} \quad (3)$$

$$v_{ij} = w_j \times r_{ij} \quad (4)$$

i = 1, 2… 5 and j = 1, 2….7

Here, x_{ij} is the original score of material i with respect to criteria j, and r_{ij} is its normalised score. v_{ij} is the weighted normalised score of material i with respect to criteria j, and w_j is the weight of the criteria j.

Table 5: Weighted normalised decision matrix

Material	PC	FE	LT	CS	BD	EI	VP
Cement	0.063	0.012	0.064	0.047	0.034	0.030	0.144
Reinforcement bar	0.135	0.012	0.054	0.041	0.038	0.069	0.143
AAC blocks	0.092	0.040	0.073	0.054	0.038	0.002	0.181
Coarse aggregate	0.042	0.015	0.043	0.054	0.034	0.002	0.142
Tiles	0.072	0.036	0.038	0.052	0.026	0.050	0.156

The next step in TOPSIS method is to determine the ideal solution. The positive ideal solution and the negative ideal solution were obtained using Eqs. (5) and (6) respectively. Here, positive criteria are PC, LT, CS, BD, EI, and VP as they have a direct relationship with MC whereas, FE is the negative criteria as it has an inverse relationship with MC.

$$A^* = \{(\max(v_{ij}) | j \in J); (\min(v_{ij}) | j \in J')\} = \{v_1^*, \dots v_n^*\} \quad (5)$$

$$A' = \{(\min(v_{ij}) | j \in J); (\max(v_{ij}) | j \in J')\} = \{v_1', \dots, v_n'\} \quad (6)$$

Here, J is the set of positive criteria whereas, J' is the set of negative criteria. For example, the weighted normalised scores of reinforcement bar (0.012) and AAC blocks (0.073) represent the positive ideal solution for FE and LT respectively while the weighted normalised scores of AAC blocks (0.040) and tiles (0.038) represent the negative ideal solution for FE and LT respectively. In the next step, separation measure from the positive ideal solution and negative ideal solution were calculated using Eqs. (7) and (8) respectively. Further, relative closeness to the positive ideal solution was determined using Eq. (9) as given in Table 6. This represents the MC values of materials which lies between 0 and 1.

$$S_i^* = [\sum_{j=1}^{n} (v_j^* - v_{ij})^2]^{1/2} \quad (7)$$

$$S_i' = [\sum_{j=1}^{n} (v_j' - v_{ij})^2]^{1/2} \quad (8)$$

$$C_i^* = \frac{S_i'}{(S_i^* + S_i')} \quad (9)$$

Table 6: Material criticality (MC) values of materials

Material	Cement	Reinforcement bar	AAC blocks	Coarse aggregate	Tiles
C_i^* (MC)	0.365	0.730	0.468	0.189	0.419

Determination of total criticality

Traditionally, in the critical path method, a critical activity is the activity which has zero float duration. Criticality increases as the float decreases. Based on this, Eq. (10) is developed for calculation of activity criticality (AC) of materials.

$$AC_k = 1 - \frac{f_k}{\Sigma f_k} \quad (10)$$

Here, AC_k is the activity criticality value of material associated with activity k and f_k is float duration of the activity. Using Eq. (10), AC values of materials were calculated as shown in Table 7. Finally, total critically (TC) of materials were determined by combining MC and AC values as shown in Table 7. Materials are ranked based on the TC values where higher TC value indicates a higher priority of material for procurement.

Table 7: Activity criticality (AC) values of materials

Material	Associated activity	Float (days)	AC	MC	TC	Rank
Cement	Slab concreting	0	1.0	0.365	0.365	2
Reinforcement bar	Slab reinforcement fixing	0	1.0	0.730	0.730	1
AAC blocks	External Wall	10	0.6	0.468	0.281	3
Coarse aggregate	Slab concreting	0	1.0	0.189	0.189	4
Tiles	Flooring	15	0.4	0.419	0.168	5

DISCUSSION

An activity may need several materials. However, criticality of the materials may not be the same. It depends on the inherent characteristics of materials and the supply environment. Cement and coarse aggregate are required for the same activity (slab concreting). It can be seen from Table 7 that cement (TC=0.365) is more critical than coarse aggregate (TC=0.189). This is because of the higher percentage contribution (PC), higher lead time (LT), higher volatility in price of material (VP), and lesser flexibility (FE) values of cement than coarse aggregate. Thus, penalty due to non-availability of cement will be more than that due to coarse aggregate.

It can be further seen that cement (TC=0.365) is more critical than AAC blocks (TC=0.281). Even though the material criticality (MC) value is lower for cement, it will be used for slab concreting which is a critical activity. However, AAC blocks will be used for a noncritical activity. This leads to higher activity criticality (AC) values of cement compared to that of AAC blocks. It is implied that penalty due to

non-availability of material can be greater for the material which has higher AC value. Therefore, it is important to incorporate AC values in material procurement decision. As shown in Table 7, it can be observed that the reinforcement bar is most critical with TC=0.730 due to its highest MC values and highest AC values. Hence in a budget constraint situation, procurement manager should give the highest priority to reinforcement bar followed by cement, AAC blocks, coarse aggregate, and tiles for procurement. Although, materials like cement, reinforcement bar, and coarse aggregate are ranked based on their TC values, these being key elements of reinforced cement concrete, an appropriate procurement strategy and supply chain decision needs to be taken for their procurement in addition to the assessment of their criticality.

CONCLUSIONS

Material management process in a construction project requires an extensive effort due to its complex nature and limited budget availability. The process can be effective if procurement is carried out by prioritising the materials based on their inherent characteristics, supply environment, and project network. Seven interdependent criteria are identified that represents the characteristics of materials and the supply environment. The material manager can directly use the weight of the criteria for evaluation of MC values in any construction project. Further, based on the inputs for the material on the given scale under each criteria, managers can determine MC values of materials in a construction project. By calculating AC values based on activity float and combining it with MC values, TC values can be calculated. The TC value represents the quantitative measure of the penalty due to the non-availability of a material. Materials with higher TC values needs greater attention from materials managers and extensive coordination with suppliers. It can be used to prioritise the material for procurement especially, in the budget constraint situation in a construction project. Prioritising materials based on it will ensure the availability of materials on time and reducing the penalty in terms of time and cost overrun.

Furthermore, penalty due to non-availability of materials or shortage cost is very difficult to quantify in a construction project and also there is no well-defined method for its quantification in the organization. However, it is an essential component for an inventory model. Therefore, TC values are proposed to be used as shortage cost coefficients of materials in the inventory model as it incorporates both material characteristics and project characteristics. To validate the model, it is planned to be implemented in an ongoing building construction project by comparing it with the existing procurement strategy in an organization. This is the part of the authors' intended comprehensive research plan. Further research is also suggested to conduct sensitivity analysis for the mentioned criteria. Even though due care was taken to select the respondents in an unbiased manner, the selection of criteria and assessment of their weights through the questionnaire survey involve subjectivity such as deficiency of conscientious responses and differences in understanding.

REFERENCES

Ahuja, V, Yang, J and Shankar, R (2009) Study of ICT adoption for building project management in the Indian construction industry, *Automation in Construction*, 18(**4**), 415-423.

Caldas, C H, Menches, C L, Reyes, P M, Navarro, L and Vargas, D M (2014) Materials management practices in the construction industry, *Practice Periodical on Structural Design and Construction*, 20(**3**), 1-8.

Dixit, V, Srivastava, R K and Chaudhuri, A (2013) Integrating materials management with project management of complex projects, *Journal of Advances in Management Research*, 10(**2**), 230-278.

Glöser, S, Espinoza, L T, Gandenberger, C and Faulstich, M (2015) Raw material criticality in the context of classical risk assessment, *Resources Policy*, 44, 35-46.

Hallstedt, S I and Isaksson, O (2017) Material criticality assessment in early phases of sustainable product development, *Journal of Cleaner Production*, 161, 40-52.

Huiskonen, J (2001) Maintenance spare parts logistics: Special characteristics and strategic choices, *International Journal of Production Economics*, 71(1-3) 125-133.

Knoeri, C, Wäger, P A, Stamp, A, Althaus, H and Weil, M (2013) Science of the Total Environment Towards a dynamic assessment of raw materials criticality: Linking agent-based demand - With material flow supply modelling approaches, *Science of the Total Environment*, 461, 808-812.

Koushki, P A and Kartam, N (2004) Impact of construction materials on project time and cost in Kuwait Engineering, *Construction and Architectural Management*, 11(**2**), 126-132.

Ku, A Y, Loudis, J and Duclos, S J (2018) The impact of technological innovation on critical materials risk dynamics, *Sustainable Materials and Technologies*, 15, 19-26.

Lapko, Y, Trucco, P and Nuur, C (2016) The business perspective on materials criticality: Evidence from manufacturers, *Resources Policy*, 50, 93-107.

Lloyd, S, Lee, J, Clifton, A, Elghali, L and France, C (2012) Recommendations for assessing materials criticality, *Proceedings of the Institution of Civil Engineers: Waste and Resource Management*, 165(**4**), 191-200.

Nieto, A, Guelly, K and Kleit, A (2013) Addressing criticality for rare earth elements in petroleum refining: The key supply factors approach, *Resources Policy*, 38(**4**), 496-503.

Purnell, P, Dawson, D, Roelich, K E, Steinberger, J K and Busch, J (2013) Critical materials for infrastructure: Local vs global properties, *Proceedings of the Institution of Civil Engineers: Engineering Sustainability*, 166(**5**), 272-280.

Saaty, T L (1990) How to make a decision: The analytic hierarchy process, *European Journal of Operational Research*, 48(**1**), 9-26.

Schilling, D R (2013) *Global Construction Expected to Increase by $ 4.8 Trillion by 2020*. Available from http://www.industrytap.com/global-construction-expected-to-increase-by-4-8-trillion-by-2020/1483 [Accessed 6th March 2019].

Statista (2017) *Construction Industry Spending Worldwide from 2014 to 2025*. Available from https://www.statista.com/statistics/788128/construction-spending-worldwide/ [Accessed 6th March 2019].

Wakchaure, S S and Jha, K N (2012) Determination of bridge health index using analytical hierarchy process, *Construction Management and Economics*, 30(**2**), 133-149.

PROJECT PLANNING AND SCHEDULING USING SYSTEM DYNAMICS FOR DEALING WITH COMPLEXITY ON CONSTRUCTION PROJECTS

Mehran Barani Shikhrobat[1], Shabnam Kabiri and Roger Flanagan

School of Construction Management and Engineering University of Reading, Chancellor's Building, Whiteknights, Reading, RG6 6DF, UK

Classical static project planning methods, such as CPM, was developed for a construction industry with more certainty, less complexity, and not having to cope with the speed of change experienced today. Many projects using traditional planning methods fail to deliver projects on time. The results are deterministic and unreliable to deliver the project objectives. This originates from ignorance of understanding the cause and effect relationships of different internal and external elements in a modern construction project. Increased complexity is one of the fundamental issues causing project failure. Planning systems must deal with increased complexity, which traditional systems do not manage. Projects can be technically complex, organisationally complex, and environmentally complex. The research uses a bottom-up approach to develop a conceptual framework to map complexity and improve the flow of information in the project planning stage of construction projects. The expectation is to understand the realistic view of project scheduling considering projects complexity and uncertainties and project factors interactions. This is based on project scheduling with simulation using system dynamics. The proposed framework in this research aims to provide an enhanced method of considering a project different parts behaviour and the consequence. This study contributed to the existing literature of understanding the complexity degree of dynamic scheduling. Furthermore, in the presented holistic analysis by identifying different complexity causes elements and prioritise those allows project planners and engineers to minimize the scheduling variance of operation in reality. There is no evidence showing this has been done before.

Keywords: scheduling, complexity, system dynamics, project planning

INTRODUCTION

Planning, sometimes called programming, is about breaking down a project into individual operations/activities/work packages and defining a logical sequence of events that will deliver a completed project. Managing the dependencies between those operations and the resources requires an understanding of the design and complexity of the project. Planning is effectively defining what is to be done and how; scheduling is the when. Providing a reliable project planning and scheduling method is increasingly important for construction projects (Serrador and Turner, 2015). Projects run over budget and over time for a variety of reasons, often the construction programme produced at the commencement of the project is wrong, based on incorrect assumptions and incomplete information. Programmes are often

[1] mshikhrobat@yahoo.com

Shikhrobat, M B, Kabiri, S and Flanagan, R (2019) Project Planning and Scheduling Using System Dynamics for Dealing with Complexity on Construction Projects *In:* Gorse, C and Neilson, C J (Eds) *Proceedings of the 35th Annual ARCOM Conference,* 2-4 September 2019, Leeds, UK, Association of Researchers in Construction Management, 689-698.

over optimistic and fail to recognise incomplete design and the overlap of design and production. Current methods and applications have remained theoretically and objectively static, using primarily deterministic planning approaches. Deterministic planning involves selecting one course of action for activities; this makes consideration of alternative options very limited and whilst CPM has float times, the programme follows a pre-determined course of action. Probabilistic planning allows for alternative course of action at the planning stage. It is more difficult to implement, because of the need for information about the different options, which presents challenges. Researches has attempted to remove or reduce the dissatisfaction with the programming systems, with little progress (Andersen, 1996; Collyer *et al.,* 2010). One important difficulty argued by Collyer and Warren (2009, 355) is that "any project has some "degree of dynamism". Dynamic is a term used in project planning as describing that a project is not characterised by a solid and predefined environment; it is influenced by constant change. This has resulted in a poor or inadequate planning expectations, which negatively links to project outcomes, and creating problems that impact on construction project management. The pre-project planning process must be recognized as a formal, well-organized planning process, with specific deliverables (Hamilton and Gibson Jr. 1996, 32). Significant project planning is designed and developed as a crucial part of the system development process (Chatzoglou and Macaulay, 1996). For project planning it is vital to distinguish between two types of contingency. Contingency can facilitate project planning by preparing several possibilities on activities of duration to minimise what time is needed for activities (Laufer and Tucker, 1987). However, construction projects are executed in a complex dynamic environment, characterized by uncertainty and risk (Schatteman *et al.,* 2008). Complex means many parts are included, often interrelated that can make the settings complicated or difficult to understand. Deterministic outcomes exist in a vacuum, frequently ignoring other influences on the work breakdown structure. Hence, planning and scheduling is not a linear process, just like design it is iterative, yet planning systems assume linearity and sequential connections. They do consider interdependence, but the problem is that planning is a system, made up of many interdependent sub-systems. The framework in this research brings a structure using system dynamics to include the entire elements of scope of project, work breakdown structure (WBS), design team, supply chain, resources, performance and objectives of a project. System dynamics is design to cope with complex systems.

Scheduling Robustness

Robust scheduling is a method of multi-objectives consideration. While in a stochastic scheduling method, the probability distribution of the uncertainty is essential; in a robust optimization, it is not necessarily required. The aim of robust optimization is to reflect flexibility by applying the possibility for the uncertainties. However, two shortcomings are important in a robust scheduling method: 1) a robust solution may suffer from poor representation on objective values truthiness; 2) the unpredictability perspective of the robust solution to variation in the uncertainty set is not considered (Coleman *et al.,* 2013). A fundamental scheduling problem as Lyneis *et al.,* (2001, 238) argues is that most project management tools assume sequential linearity, with the belief that interconnected activities are controllable. They either (1) view a project statically, or (2) take a partial, narrow view to allow managers to cope mentally with the complexity. Such approaches are unrealistic in practice because regular or irregular surprises and uncertainties arise in project execution, many of which are uncontrollable, they can cause disruptions on scheduling. Nevertheless, "a

project schedule can rarely be implemented exactly in a realistic project environment such that the planned optimal project completion time is achieved" (Yang 1996, 256). Due to frequent re-scheduling, scheduling disruptions increases the complexity of scheduling system (Herroelen and Leus, 2004). The validity of project scheduling with its static deterministic products have been severely critiqued (Goldratt, 1997). The consequences of those uncertainties on project performance creates severe damage to the original expectations. Consequently, any generated solution of these approaches is becoming absolute from the starting point of project execution. Herroelen and Leus (2004, 550) highlighted that "the development of a pre-computed baseline schedule (pre-schedule) with the objective of assuring stability in the start times of the activities, rather than the minimization of the expected project duration or some other regular objective function, has been mostly overlooked so far".

Scheduling Methods, Complexity Variables and Degree

Traditional planning systems such as CPM and PERT fail to take account of complexity, which results from uncertainty and the dynamic environment of a construction site. Fuzzy logic, stochastic scheduling, and sensitivity analysis do not solve the problem of better decisions, because they rely on optimization. A new approach is needed that can measure complexity at the outset of a project to alert the site production team. Gidado (1996) summarises the complexity meaning from the interview results from expert's viewpoint of construction projects into two managerial and technical perspectives. Understating the effects of strategies, policies and techniques that are having impacts on the performance are underlined in the research of Vieira *et al.,* (2003). Rather than focusing on minimizing the number of activities, they presented an alternative justification for decreasing the complexity index. Complexity index describes as a developed method to define complexity as practised (Mattsson *et al.,* 2012). Kamburowski *et al.,* (2000) states that understanding the complexity index (CI) of scheduling network of project management techniques is the most fundamental factor. However, in the event that the number of nodes is not limited or not clearly well-known, has found hard to decreasing complexity index (CI) factor. Furthermore, Bregman (2009) to control the probability completion for pre-defined due dates, introduced a dynamic matrix simulation method for selecting possibilities. In this research, the uncertainty sources are excluded. Therefore, many reality behavior of project's activities may not be included. Ouelhadj and Petrovic (2009) divided dynamic scheduling into resource-related and job-related categories. Resource-related are human resources, material shortages, operational machine failure, and delays based on resources preparation. Job-related are changes on due dates, priority changes, time processing changes, and new activities arrival or removal. In reality, construction projects are highly dynamic and dealing with complexity and uncertainty. This emerge scheduling a consideration for the purpose of effective planning success. Thus, it is vital to understand the major variables of scheduling complexity. Faniran *et al.,* (1998) literature review from various studies have highlighted scope of project, work breakdown structure (WBS), design team, supply chain, resources, performance and objectives as the main variables of construction project planning and scheduling. Therefore, dynamic scheduling method in this study focus is to present a framework of understanding expectations based on complexity degree towards a focus on the dynamic interactions between complexity, influencers and objectives within which project operates. For this aim, understanding the system thinking idea as a purposive classification, and the significance of "system's boundaries" and "interfaces" is essential. This can improve the

understanding of project scheduling system in an imperfect word dealing with complexity, interdependence, uncertainty, risk, constant changes, speed of change and properties that are out of control. However, the literature review found no evidence showing how to consider complexity degree as a technique of understanding and controlling uncertainties to achieve the desired scheduling objectives.

METHODOLOGY

Dynamic Scheduling Framework

In reality, the intended pre-plan structure is constantly changes regarding to dynamic behaviour of construction projects. The dynamic behaviour that increases the complexity of project scheduling. Figure 1 shows the proposed conceptual framework. This includes two different variables consisting of controllable and uncontrollable. Controllable variables are referring to the variables that are in control of project management team. Controllable variables used in this framework are consisting of scope of project, work breakdown structure (WBS), design team, supply chain, resources, performance and objectives. Also, uncontrollable variable is referring to those that are out of control for instance weather changes or inflation rate changes. This is turned up as externalities variable in the proposed framework. Furthermore, system dynamics is used in dealing with cause-effect and stock and flow diagrams analysis to understanding the complexity degree of pre-plan scheduling. Design and implementation of dynamic scheduling conceptual framework is shaped by using systems thinking and system design. The conceptual framework proposed in this research enables project scheduling derived by practitioners and engineers to be more realistic. Therefore, the project scheduling conceptual framework proposed aim is to understand the dynamic scheduling elements used to analyse the complexity degree. This is leading to considerate the flow of changes regarding to complexity degree on the desired objective. These essential factors are targeted to decrease the scheduling variance as aimed in the research. However, this may include a broad range of further objectives depends on a specific scheduling plan. This is regarding to different internal and external parties, limitations and expectations to operate a finalized plan.

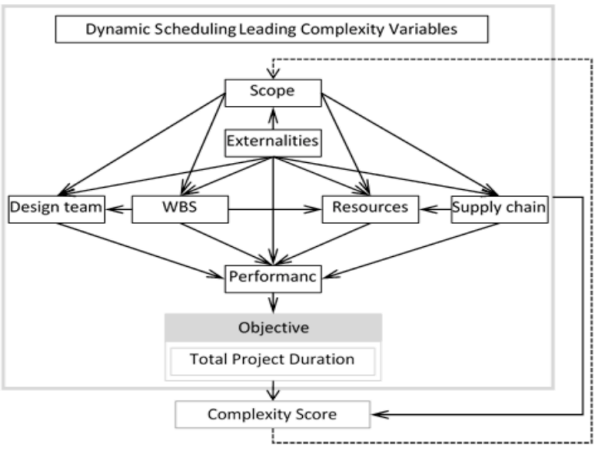


Figure 1: Dynamic scheduling for complexity control model

Figure 1 proposed a model for complexity control of a dynamic scheduling. Total project duration expectation, a more reliable scope, understanding scheduling expectations that are not considered in the initial scheduling and those changes that may appear in further steps, a brighter understanding of the total project duration of

estimation. The classical scheduling tools and techniques are not practically designed to include the complexity degree, for instance CPM and PERT. The proposed framework is capable to build a bridge between targeted objective and reality of dynamic behaviour of construction projects by considering the complexity degree constructed on both controllable and uncontrollable variables.

System Dynamics Used in Modelling

The application of system dynamics was proposed Jay Forrester (1961) in the book on Industrial Dynamics. System dynamics was developed by engineers as either the strategic management design or decision-making tool across different industries from construction to manufacturing and IT development (Rodrigues and Bowers, 1996). The system dynamic emphasis is on understanding the dynamic form and the internal interactions role of different variables in reality of a system. It "addresses problematic behaviour patterns caused primarily by the feedback structure of the setting" (Barlas 2007, 470). The main focus of system dynamics is on dynamic changes and the strength of the interactions of elements over time. The four basic elements of the system dynamics method (Richardson, 2011) are 1) information of feedback from systems theory, 2) understanding of decision-making procedure, 3) the empirical approach of complex method, and 4) the simulation of realistic assumptions. Multiple influencers with negative and positive feedback are the behaviour modes of nonlinear systems. For the structure theory of the model, it is initiated a four substantial level mode consisting of "The Closed Boundary", "The Feedback Loop", "Levels" and "Flows" (Forrester 1968, 406). The model can capture reactions and delays in time in a broad margin of limitations (Sterman, 2002). System dynamics is not a model to create, but to solve the systematic issues reflected in a management behaviour. The benefits of using system dynamics varies from "strategy support" to managing industry changes (Dangerfield *et al.,* 2010, 411). One of the most significant tasks in the development of system dynamics is the model conceptualisation (Luna-Reyes, 2003). Randers (1980, 117) introduced an "effective procedure" of "model conceptualisation", consisting of 1) conceptualisation, 2) formulation, 3) testing and 4) implementation. Conceptualisation defines the questions to be addressed, sets the boundaries of the system, time distribution, and describe the casual diagram form as the basic mechanism. Formulation to conjecture of detailed structure. Testing either model assumptions or the dynamic behaviour. Implementation to understanding the model behaviour. The content is on understanding how to control the complexity as the core factor of project scheduling and planning variance based upon understanding the relationships between the complexity factors (influencers) and scheduling objectives.

DATA ANALYSIS

Expected Value Factors and Weight Scores

Eight factors are weighed, making a matrix of eight column and eight rows. The factors are the scope of project, work breakdown structure (WBS), design team, supply chain, resources, externalities, performance and objectives. This needs to be combined with a decision-making method for instance Analytic Hierarchy Process (AHP). AHP is developed by (Saaty, 1980) and is known as a decision-making process. It aims to quantify the priorities from a set of relative objectives based on the judgment with considering multi-criteria factors. The focus of AHP method is to understand the consistency of the alternative comparison in the process of decision-making (Saaty, 2008). It is able to organise factors in a systematic and structured way

with simple clarification to the decision-making difficulty (Skibniewski and Chao, 1993). The weight factor is generally a measure of relative quantity meaning for each objective. Furthermore, selecting weight is to reflect the preference of the objectives. AHP method identifies the accurate weight for factors used in the matrix organization analysis of related accurate eigenvectors (Forman and Gass, 2001). (Saaty, 2008) considered for steps for AHP process. First, developing a matrix to determining the hierarchy organisation for instance. Then, developing the matrix to show a set of comparison pairwise. After, consistency evaluation for the judgment, and finally, prioritising.

$$S = \begin{pmatrix} \frac{a1}{a1} & \frac{a1}{a2} & \cdots & \frac{a1}{an} \\ \frac{a2}{a1} & \frac{a2}{a2} & \cdots & \frac{a2}{an} \\ \cdots & \cdots & \cdots & \cdots \\ \frac{an}{a1} & \frac{an}{a2} & \cdots & \frac{an}{an} \end{pmatrix} * \begin{pmatrix} w1 \\ w2 \\ \cdots \\ \cdots \\ wn \end{pmatrix} = \lambda max * \begin{pmatrix} w1 \\ w2 \\ \cdots \\ \cdots \\ wn \end{pmatrix} = \begin{pmatrix} b1 \\ b2 \\ \cdots \\ \cdots \\ bn \end{pmatrix} \quad \text{(equation 1)}$$

Which $\lambda max = \left(\frac{1}{n}\right) * \sum_{i=1}^{n} \frac{bi}{wi}$ (equation 2); Consistency Index (CI) = (λmax - n) / (n - 1) (equation 3); Consistency Ratio (CR) = CI / RI (Average Random Consistency Index (RI) (equation 4) is taken from the following table 1 presented by (Saaty, 1980)).

Table 1: Average random consistency (RI)

Strength	Quantity	Description
A	1	A and B are equally important
B	3	A is moderately more important than B
C	5	A is strongly more important than B
D	7	A is much more important than B

The eight factors presented in dynamic scheduling framework (Figure1) prescribed in an 8*8 matrix shown in Table 3.

Table 3: A Pairwise comparison of factors in AHP

	Scope	Externalities	Design team	WBS	Resources	Supply chain	Performance
Scope	0.20	1	1	5	1	1	1
Externalities	0.20	1	1	1	1	1	1
Design team	0.14	0.20	1	1	1	1	1
WBS	0.33	1	1	1	1	1	1
Resources	0.14	1	1	1	1	1	1
Supply chain	0.20	1	1	1	1	1	1
Performance	0.20	1	1	5	1	1	1
Objective	1	1	1	1	1	1	1
Total	3.22	11.20	12.00	18.00	10.00	14.00	12.00

The random index is equal to 1.40, and therefore the consistency ratio is equal to 0.02.

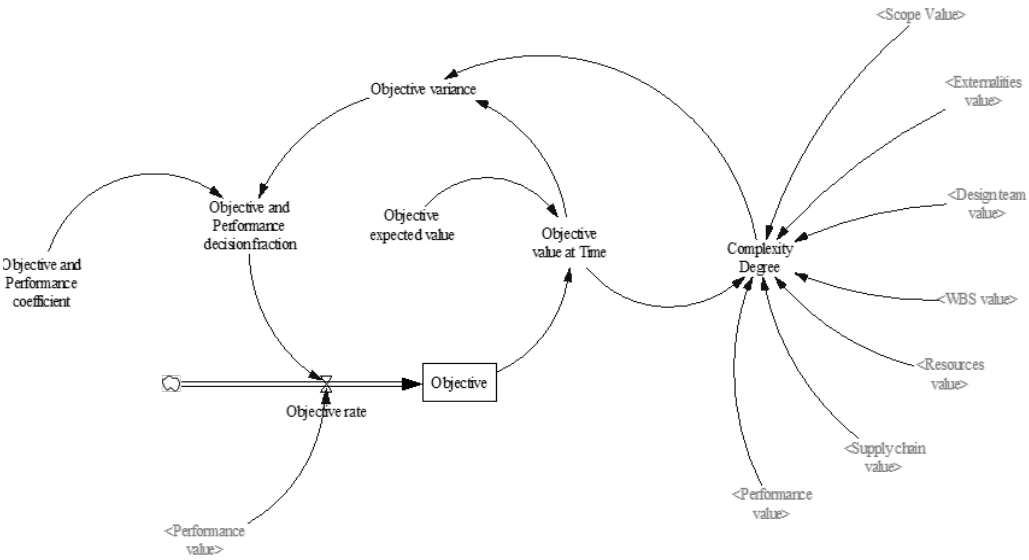
The final stage shown in Table 4, is to use a mathematical method, for instance Least Square Linear regression to understand the coefficients between different variables presented in Figure 1.

Table 1: Summary of factors coefficients

Variables	Dependants	Coefficient
Design team	Externalities	0.48
Design team	Scope	0.25
	Externalities	0.46
	WBS	0.27
WBS	Scope	0.16
	Externalities	0.26
Resources	WBS	0.17
	Externalities	0.08
	Scope	0.17
Supply chain	Scope	0.23
	Externalities	0.18
Performance	Design team	0.22
	WBS	0.11
	Resources	0.04
	Supply chain	0.35
	Externalities	0.21
Objectives	Performance	0.03

System Dynamics Model Development

The system dynamics model presented in Figure 2 shows that dynamic scheduling allows consideration of the possible uncertainties regarding the complexity of project scheduling.



Simulation Results

Dynamic project scheduling using system dynamics are simulated using Vensim software. The results consist of different components of scheduling complexity control, dynamic scheduling information and objectives. The simulation graphs demonstrate the behaviour of different component over time shown in Figure 3.

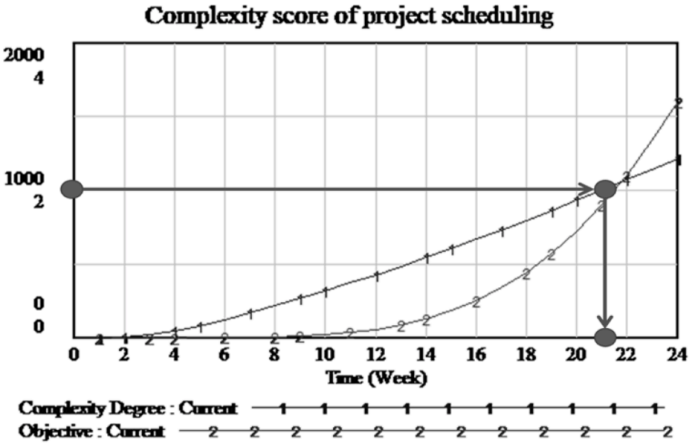


Figure 3: Complexity and Total Project Duration over time

Figure 3 illustrates the changes of both the complexity degree and objectives for a project with 11 weeks period. Initial value for all variables is planned at 1000 for the running period. The graph shows to reach the 1000 value assumed in the case study; the objectives are changing too. The total project duration with considering complexity degree based on the given assumptions is equal to 21 weeks.

CONCLUSIONS

This paper proposes a new approach by using system dynamics to identify causal loops and flow components to help in the planning and scheduling process. The technique needs further development and testing, but the idea is to stimulate a new approach to producing more reliable planning and scheduling. The dynamic scheduling model will be validated by more case studies in further steps of the research.

REFERENCES

Ackoff, R (1970) A concept of corporate planning, *Journal of the Operational Research Society*, 22(**2**),193-194.

Allam, S I G (1988) Multi-project scheduling: A new categorization for heuristic scheduling rules in construction scheduling problems, *Construction Management and Economics*, 6,93-115.

Andersen, E S (1996) Warning: Activity planning is hazardous to your project's health! *International Journal of Project Management*, 14(**2**), 89-94.

Barlas, Y (2007) Leverage points to march 'upward from the aimless plateau', *Built Environment*, 23(**4**), 469-473.

Belhe, U and Kusiak, A (1997) Dynamic scheduling of design activities with resource constraints, *IEEE Transactions on Systems*, 27(**1**), 105-111.

Bregman, R L (2009) A heuristic procedure for solving the dynamic probabilistic project expediting problem, *European Journal of Operational Research*, 192, 125-137.

Chatzoglou, P D and Macaulay, L A (1996) A review of existing models for project planning and estimation and the need for a new approach, *International Journal of Project Management*, 14(**3**),173-183.

Coleman, T F, Moazeni, S and Li, Y (2013) Regularized robust optimization: The optimal portfolio execution case, *Computational Optimization and Applications*, 55(**2**), 341-377.

Collyer, S and Warren, C M J (2009) Project management approaches for dynamic environments, *International Journal of Project Management*, 27(**4**), 355-364.

Collyer, S, Warren, C, Hemsley, B and Stevens, C (2010) Aim, fire, aim-project planning styles in dynamic environments, *Project Management Journal*, 41(**4**), 108-121.

Cowling, P and Johansson, M (2002) Using real time information for effective dynamic scheduling, *European Journal of Operational Research*, 139, 230-244.

Dangerfield, B, Green, S and Austin, S (2010) Understanding construction competitiveness: the contribution of system dynamics, *Construction Innovation*, 10(**4**), 408-420.

Dumond, J and Mabert, V. A (1988) Evaluating project scheduling and due date assignment procedures: An experimental analysis, *Management Science*, 34(**1**), 101-118.

Egan, J (1998) Rethinking construction: Report of the construction task force on the scope for improving the quality and efficiency of UK construction, *Structural Engineer*, 80(**14**), 2.

Faniran, O O, Oluwoye, J O and Lenard, D J (1998) Interactions between construction planning and influence factors, *Journal of Construction Engineering and Management,* 124(**4**), 245-256.

Fisher, A C, Liebman, J S and Nemhauser, G L (1968) *Computer construction of project networks*, *Communication of the ACM*, 11(**7**), 493-497.

Forman, E H and Gass, S I (2001) The Analytic Hierarchy Process: An Exposition, *Operations Research*, 49(**4**), 469-486.

Forrester, J W (1968) Industrial dynamics - After the first decade, *Management Science*, 14(**7**), 398-415.

Gidado, K I (1996) Project complexity: The focal point of construction production planning, *Construction Management and Economics*, 14(**3**), 213-225.

Goldratt, E (1997) *Critical Chain*. Great Barrington, MA: The North River Press.

Hamilton, M R and Gibson Jr, G E (1996) Benchmarking preproject planning effort, *Journal of Management in Engineering*, 12(April), 25-33.

Herroelen, W and Leus, R (2004) The construction of stable project baseline schedules, *European Journal of Operational Research*, 156(**3**), 550-565.

Kamburowski, J, Michael, D J and Boulevard, E L C (2000) Minimizing the complexity of an activity network, *Networks*, 36(**1**), 47-52.

Kotter, J P (1995) Leading change: Why transformation efforts fail the promise of the governed corporation, *Harvard Business Review*, (March-April), 59-67.

Krishnamoorthy, M S and Deo, N (1979) Complexity of the problem in a Pert network, *Networks*, 9, 189-194.

Laufer, A and Tucker, R L (1987) Is construction project planning really doing its job? A critical examination of focus, role and process, *Construction Management and Economics*, 5(**3**),243-266.

Luna-Reyes, L (2003) Model conceptualization: A critical review, *In: Proceedings of the 21st International Conference of the System Dynamics Society*, 1-11.

Lyneis, J M, Cooper, K G and Els, S A (2001) Strategic management of complex projects: A case study using system dynamics, *System Dynamics Review*, 17(**3**), 237-260.

Mattsson, S, Gullander, P, Harlin, U, Bäckstrand, G, Fastha, Å and Davidssond, A (2012) Testing complexity index - A method for measuring perceived production complexity, *Procedia CIRP*, 3, 394-399.

Monroy-licht, M and Alberto, C (2017) The rescheduling arc routing problem, *International Transactions in Operational Research*, 24, 1325-1346.

Morris, P W G (1983) Managing project interfaces - Key points for project success, *Project Management Handbook*, 16-55.

Ouelhadj, D and Petrovic, S (2009) A survey of dynamic scheduling in manufacturing systems, *Journal of Scheduling*, 12(**417**).

Randers, J (1980) *Guidelines for Model Conceptualization, Elements of the System Dynamics Method*. Cambridge, MA: MIT Press, 117-139.

Richardson, G (2011) Reflections on the foundations of system dynamics, *System Dynamics Review*, 27(**3**), 219-243.

Rodrigues, A and Bowers, J (1996) The role of system dynamics in project management, *International Journal of Project Management*, 14(**4**), 213-220.

Saaty, T L (2008) Decision making with the analytic hierarchy process, *International Journal of Services Sciences,* 1(**1**),83-98.

Saaty, T L (1980) *The Analytic Hierarchy Process*. New York: McGraw-Hill.

Schatteman, D, Herroelen, W, Vonder, S Van De and Boone, A (2008) Methodology for integrated risk management and proactive scheduling of construction projects, *Journal of Construction Engineering and Management*, 134(11), 885-893.

Serrador, P and Turner, R (2015) The relationship between project success and project efficiency, *Project Management Journal*, 46(**1**), 30-39.

Skibniewski, M J and Chao, L (1993) Evaluation of advanced construction technology with AHP method, *Journal of Engineering Management*, 118(**3**), 577-593.

Sterman, J D (2002) *System Dynamics: Systems Thinking and Modeling for a Complex World*. Cambridge: Cambridge University Press.

Stoop, P P M and Wiers, V C S (1996) The complexity of scheduling in practice. *International Journal of Operations and Production Management*. 16(**10**), 37-53.

Vieira, G E, Herrmann, J W and Lin, E (2003) Rescheduling manufacturing systems: A framework of strategies, policies and methods, *Journal of Scheduling*, 6, 39-62.

Yamamoto, M (1985) Scheduling/rescheduling in the manufacturing operating system environment, *International Journal of Production Research*, 23(**4**), 705-722.

Yang, K K (1996) Effects of erroneous estimation of activity durations on scheduling and dispatching a single project, *Decision Sciences*, 27(**2**), 255-290.

CONSTRUCTION PLANNING WITH MACHINE LEARNING

May Shayboun, Dimosthenis Kifokeris and Christian Koch[1]

Division of Construction Management, Department of Architecture and Civil Engineering, Chalmers University of Technology, Sven Hultinsgatan 6, Gothenburg, Sweden 41296, Sweden.

Over the next years, it is expected that machine learning will be widely implemented within fields in the construction context, such as construction planning. As construction projects tend to be influenced by interrelated issues resulting in cost and/or time overruns and lower performance, it has been continuously attempted to develop predictive planning methods and tools, in order to mitigate such issues. This study aims at investigating possible applications of machine learning for construction planning, noting their impact on project performance, and finally commenting critically on the issues of responsibility in action-taking, accountability in decision-making, and the still crucial need for human reasoning. Methodologically, a literature review on machine learning applications in construction project planning is carried out, and then two particular implementation cases are selected for a more in-depth analysis. The first case draws on a productivity survey of construction projects in Sweden, where the relative data is analysed to find the most influential factors behind project performance; then, statistical correlation is used to find the features that are strongly correlated with four performance indicators (cost variance, time variance, and client- and contractor satisfaction), and a supervised machine learning analysis is done to develop a model for predicting project cost, time and satisfaction. The second case elaborates on the appraisal of constructability of civil engineering projects through technical project risk analysis; the model utilizes both unsupervised machine learning for the understanding and pre-processing of data, and supervised machine learning for the development of the predictive system. Following the above analysis, it is argued that there is a need for human reasoning in construction planning, even more so after the introduction of machine learning. It is not enough to include human aspects in the machine learning modelling; it is also crucial to strengthen qualified reasoning in the decision-making for construction project planning and being responsible in action-taking and accountable in decision-making.

Keywords: information technology, machine learning, human reasoning

INTRODUCTION

Construction projects are usually affected by multiple and interrelated factors which have a direct impact on their performance (e.g. cost and time of delivery) and productivity, such as poor management practices, unclear goals and performance measure, and crises orientation (Forbes and Ahmed 2010). Construction projects suffer from scheduling problems related to the optimal sequencing of activities and resource allocation (Zhou *et al.,* 2013, Wauters and Vanhoucke 2014). There are also problems associated to uncertainties in design, construction management and decision making (Lu *et al.,* 2012). Among cases such as the aforementioned, and regardless of

[1] christian.koch@chalmers.se

Shayboun, M, Kifokeris, D and Koch, C (2019) Construction Planning with Machine Learning *In:* Gorse, C and Neilson, C J (Eds) *Proceedings of the 35th Annual ARCOM Conference,* 2-4 September 2019, Leeds, UK, Association of Researchers in Construction Management, 699-708.

emerging performance measures (such as ones related to safety and environmental impact), delivery cost and time are still considered most important for construction planning and construction project performance evaluation (Chan and Chan 2004).

In tackling such issues within construction planning, as well as within the ongoing digitalization transformation of the construction sector, machine learning (ML) can play an important role both in research and practice (Kaplan and Haenlein 2019). Systems that utilize ML are "computer systems that automatically improve through experience" (Jordan and Mitchell 2015, Witten *et al.,* 2016, Portugal *et al.,* 2018). In this context "experience" means new data from the domain of the system. For ML to identify and verify any fundamental statistic, computational, and information theory laws that govern the respective learning systems in the relative contexts (Jordan and Mitchell 2015), it utilizes tools from, among other fields, data mining, statistics, and optimization theory (Jordan and Mitchell 2015).

ML is frequently classified in three types: supervised, unsupervised, and hybrid ML. Supervised ML (Jordan and Mitchell 2015) utilizes algorithms that are "trained" and validated using labelled datasets, within application domains with a known reasoning. ML algorithms "learn" based on real training data, produce certain results, and then, after the results' validation, apply the gained knowledge on new instances (Portugal *et al.,* 2018). Unsupervised ML can be defined as "the analysis of unlabelled data under assumptions about structural properties of the data" (Jordan and Mitchell 2015). In unsupervised ML, the system is presented with data about a domain and has to find hidden patterns and develop relational models "on its own", by running internal procedures (Portugal *et al.,* 2018). Counter to supervised ML, there are not pre-set assumptions about internals laws in the dataset; rather, unsupervised ML systems are supposed to find these. Hybrid ML involves mixing more than one approaches. These may include semi-supervised learning, or reinforcement learning (Jordan and Mitchell 2015, Portugal *et al.,* 2018).

ML can potentially provide powerful data-driven predictive models but is also exposed to scepticism on issues of accountability, surveillance, and direct impact on humans (e.g. fairness, bias, and discrimination) (Whittaker *et al.,* 2018). Currently, there is difficulty in recognizing the differences in the potential between earlier ML applications (i.e. expert systems), and the current systems; this is mainly related to the ability of ML systems to process large amounts of data and rules. However, such criticism does not prevent "intelligent machines" from being considered as the new means for effective construction management, utilized along knowledge management and organizational learning, and combining human learning with computational intelligence to solve the related construction planning problems (Zhou *et al.,* 2013).

This study aims at investigating possible applications of ML for construction planning, and especially noting their impact on the responsibility in action-taking, accountability in decision-making, and the still crucial need for human reasoning. After presenting the research method, a literature review on ML applications in construction project planning takes place, and then two particular implementation cases are selected for a more in-depth analysis. In the final two sections of this paper, the discussion emanating from the conducted analysis, as well as the relative conclusions, are respectively showcased.

METHOD

In the current study, a combination of interpretive sociological and mixed method is adopted as a research approach (Bryman and Bell 2011, Creswell and Clark 2011). This approach is applied to the literature review and the exposition of the two case studies included in the succeeding sections. The literature review is based on an explorative search on current ML applications for construction planning. Then, the two cases presented were chosen from the authors' own work (a master's thesis and a PhD) and represent current applications of ML in a construction management context, with an emphasis on construction planning as well.

The example findings are relatively few, but in a targeted manner, since the authors chose to mainly present cases with well-defined systems displaying a clear methodological and developmental process, and also having reached at least the technological maturity stage of prototype. It should be noted that the literature findings both satisfying the aforementioned broad criteria and also regarding construction planning more explicitly, are even fewer, with some of them shown in Table 1.

Table 1: Reported machine learning systems within construction planning

Case system /reference	Place	Algorithms	Data	Maturity
Litigation Site Disputes/ Mahfouz and Kandil 2011	Support	4	400 projects	Prototype - Internal validation
Cost Performance and use of technology/Chi *et al.,* 2012	Support	4	193 projects	Prototype - External validation
Productivity and environment/ Liu *et al.,* 2018	Planning	2	Projects/other sources	Prototype - Internal validation
Location on site resources/ Won *et al.,* 2018	Planning	1	192 data instances	Prototype - Internal validation

The limitations of the present contribution include the selective set of literature, and a reduced context appreciation in the two cases. The first presented case limitations include not using the nuanced distinctions highlighted in the data it was built on, and rather aiming at making a general comparison between projects. Moreover, the study only covered the Swedish construction market, as the applicability to other contexts (i.e. the construction sectors in other countries) was not known. In addition, cost, time and satisfaction were selected and considered as KPIs, and other possible indicators are disregarded. The second presented case limitations stem mainly from the limited, if diverse, training and validation dataset. Furthermore, while it strives for generalized results, the diversity of the model inputs may make its particularization in distinct construction project types and/or other special conditions cumbersome.

LITERATURE REVIEW

Central activities in construction planning is scheduling, optimization and resource leveraging. Zhou *et al.,* (2013) in their review map a series of existing pre-ML algorithms and claim that ML algorithms can present an optimal method to learn flexibly and automatically from sample data, and suggest that cost, time, risk, and quality were considered. Prayogo *et al.,* (2018) presented an ML application for solving the resource leveraging problem in construction projects. Zhou *et al.,* (2013) and Prayogo *et al.,* (2018) underpin a wide potential for use of ML in construction planning. When it comes to presented systems in the literature however, a much more limited sample is available at present. Table 1 juxtaposes four found examples, where

only two are within planning in a strict sense. For each system, its place in the building process, number of used algorithms, data source, and technological maturity (i.e. is it a research model, prototype or product offered on the market?), is displayed.

The litigations of site disputes system (Mahfouz and Kandil 2011) aims at reducing site disputes through prediction of outcomes. Mahfouz and Kandil (2011) collected federal court data and separated the cases into the ones judged in favour of the client and the ones in favour of the contractor. Then, they deployed four ML algorithms on features such as project types and contract clauses and developed a model to predict the outcomes of such contractual disputes. Chi *et al.,* (2012) proposed a system for decision support, utilizing data on the degree of utilized technology and cost performance in construction projects. To process this data, they used four different ranking algorithms for project work functions. Then, they chose the highest-ranking attributes showcasing the best capability for predicting cost performance (e.g. including planning and execution, and project scoping). Liu *et al.,* (2018) proposed a system analysing scaffolding productivity and weather conditions. Liu *et al.,* (2018) claim that the relationship between outdoor ambient environment and construction productivity is nonlinear, thus a relative nonlinear model is proposed. Different nonlinear algorithms were used to study the ambient environment contributors on scaffolding construction performance factors. The collected and utilized data included performance factors (e.g. total planned hours), and ambient environment features and meteorological conditions (e.g. temperature and humidity).

A combination of meteorological conditions was found to affect the construction performance of scaffolding in Darwin Australia. Won *et al.,* (2018) propose a system for locating on-site resources. The on-site locations of stocked and installed materials are sometimes determined by radio frequency identification (RFID) sensors, which are inefficient in terms of cost and time in large projects, especially if workers are manually carrying RFID radars to investigate tags on materials (Won *et al.,* 2018); this way, intensive labour working time is required. Won *et al.,* (2018) proposed a model for the unmanned aerial vehicle UAV-RFID, utilizing algorithms to analyse data regarding the received signal strength index (RSSI), or derived by real-time kinematic (RTK) GPS and the gyro sensors mounted on the vehicle. This model was considered to be more efficient than previous methods for locating resources in outdoor sites, such as RFID, GPS, and ultra-wide band (UWB).

Summing up, there is a variety of systems and prototype applications of ML within the construction context. The purpose of the development of such systems covered various aspects of the construction field, but only a handful of the ML solutions related more explicitly to construction planning. For these systems to be developed, different ML algorithms, interfaces, and connected interoperable systems were used. The technological maturity of those is generally low (prototype stage), and their validation largely utilized internal processes (e.g. cross-validation with instances of the training dataset), rather than extensive testing through new cases. What can be underpinned is that while there is a still growing interest and promise in the research literature regarding ML applications for construction, more ground has to be covered for this interest to transform into actual established knowledge fully integrated within the construction context.

Cases

Performance prediction for Swedish construction projects

Machine learning algorithms were used to extract and analyse project performance data from a productivity survey of n = 580 construction projects in Sweden (Koch and Lundholm 2018). This data included answers from 324 main contractor representatives and 256 clients, both of whom participated in a questionnaire survey. A main ambition of the investigation was to measure productivity as something more than just cost per square meter. Process-related and soft aspects were considered, such as disturbances during construction production, and the performance of the project organization members (i.e. clients, consultants, contractors, and suppliers). The questionnaire included a set of questions that mostly had pre-given categories for answers in Likert scales. Such categories included technical project complexity, preparation work, blasting work usage, level of prefabrication, and chosen structural engineering technology (e.g. concrete, steel, or timber). In addition, project organization questions were included, such as ones about the clients' and contractors' evaluation of the consulting engineers, the architect and supplier performance, and the level of collaboration throughout projects. There were also questions where facts and figures were demanded, as well as some open questions related to stated definitions (e.g. client costs and partnering). Finally, a few questions were open without stated definitions, including ones on satisfaction, disturbances and lessons-learned. The design and operation of data collection was conducted in the autumn of 2014.

The focus was on four key performance indicators (KPIs): cost, time, and client- and contractor satisfaction. The data was related to several factors, including project attributes, external factors, and the project organization. For the ML analysis and modelling of the factors affecting project performance, several algorithmic tools were used, with the relative computational processes performed via WEKA (Waikato Environment for Knowledge Analysis), a data mining and ML software (Witten *et al.,* 2016). In the first part of the modelling, the features of time variance, cost variance and satisfaction of the contractor during the pre-construction and construction phases, as well as the cost variance and satisfaction of the client during the pre-construction and construction phases, were selected. By this feature selection, the number of input variables used to build the prediction model was reduced, and the attributes with the most distinctive predictive capability in relation to the output were identified (Witten *et al.,* 2016). Next, an analysis was performed using the selected features, so that the prediction model could find the correlation between those features and the level of project performance in terms of the four aforementioned KPIs. The error estimate used in this analysis was the root mean square error (standard deviation of residuals), namely the root of the square value of the difference between the predicted and the actual value (Witten *et al.,* 2016).

Among other features, project technical complexity, the use of blasting work, and the level of prefabrication were recognised as important factors that affect project performance within construction planning. However, despite external factors and technical aspects of a building being considered important, the most recurring factors behind project performance were human-related (such the role of the client and the level of the architect's performance). The data shows high variation in cost and time variance, and the analysis highlights that in extreme cases (which actually constitute a minority within the dataset), the performance of projects that show high cost overrun or extreme savings is harder to predict.

Constructability appraisal through risk source identification and assessment
The second case of a ML-enabled predictive system for construction planning, appraises a project's constructability through technical project risk source analysis. The constituents of this system were developed using both unsupervised ML (Kifokeris and Xenidis 2018) and supervised ML (Kifokeris and Xenidis 2019a). Constructability can be here understood as the optimal use of construction knowledge and experience in planning, design, procurement, and field operations to achieve the overall project objectives of time, cost, quality and client satisfaction, and it is an integral construction management framework implemented through the initiation, execution, and delivery project lifecycle phases (Kifokeris and Xenidis 2019a).

Firstly, the development of the system encompassed an extensive literature study on constructability and technical project risk analysis. In this review and among other findings, the definitional discrepancy regarding the notion of risk, as well as the current research trends promoting the use of risk sources (rather than risks themselves) for building and construction projects, were identified (Kifokeris and Xenidis 2018). Then, this data was used for the derivation of risk sources via unsupervised ML; it was extracted from the respective body of literature and was processed with a semantic and linguistic clustering algorithm. This resulted in the identification of 129 general technical project risk sources, organized into ten contextual overhead clusters.

Secondly, the data used for the integration of constructability and construction risk analysis via the training and validation of supervised ML, was collected through unstructured interviews with experts. The latter dataset, consisting of constructability class- and risk analysis-related data, consisted of 30 civil engineering projects. These included, among others, a biogas power plant (Greece), two bridges (Greece and Romania), the expansion of a municipal primary school (Greece), reconstruction of a municipal road axis (Greece), sustainable public installations (including a public square, Greece), four road infrastructure projects (Estonia), three renewable technology projects (Greece and Albania), four municipal electrical lighting projects (Greece), and 10 subcontracted projects forming parts of the Midfield Terminal megaproject, in the Abu Dhabi Airport. The supervised ML system that was developed utilized a variety of algorithms and auxiliary mathematical and programming tools; it linked the previously found 129 risk sources with the risk-related real data from the latter 30-project dataset, and then correlated the outcome of this linking with the constructability class-related data of the 30 projects (Kifokeris and Xenidis 2019a). As a result, and after the simultaneous training and validation of the utilized algorithms, a classification scheme able to predict the constructability of a construction project when given the values of the identified general risk sources affecting it, was produced (Kifokeris and Xenidis 2019a). Finally, the software prototype RISCONA (RIsk Source-based CONstructability Appraisal) was created (Kifokeris and Xenidis 2019b), which offered a simple graphical user interface for using the predictive model, while the computational supervised ML apparatus is running in the background.

DISCUSSION

ML has been tested in several activities related to project performance, productivity and planning. The ML literature shows that relative solutions are covering problems in scheduling, uncertainties, cost and time planning issues in construction. Scheduling and resource leveraging are urgent issues related to adequate planning of construction projects, the schedule optimization (Prayogo *et al.,* 2018, Zhou *et al.,* 2013), and the

ranking of project work-related functions (Chi *et al.,* 2012). The function ranking model provides a flexible tool for prioritising work functions, which facilitates the decision-making of construction managers by scoring identified key project elements and evaluating project management practices (Chi *et al.,* 2012). ML for the localization of resources (Won *et al.,* 2018) and the appraisal of the effect of the outdoor ambient environment on the productivity of construction tasks (Liu *et al.,* 2018) can also offer solutions for construction planning-related issues (such as the optimization of task efficiency, and project delivery time and cost); this is due to the respective models being related to success factors such as site conditions, follow-up and on-site supervision, and productivity during construction. ML models for predicting the litigation of disputes (e.g. related to site conditions) (Mahfouz and Kandil 2011), can aid in solving problems related to economic and external factors. There is a direct correlation between these factors (also affecting construction project performance) and effective construction planning, and the prediction results of the former can affect the latter. Regardless of the advancement of ML models supporting construction planning (which influences and is influenced by the level of project performance), there are dimensions that still need to be investigated and realized into practical solutions for the related problems - such as uncertainties in design (Lu *et al.,* 2012). It is also a common point in the literature that there are limitations in validating the reliability and efficiency of ML models developed for descriptive and predictive purposes within construction planning; there is a need for more diverse project outcomes and project management practices to be considered, and for the investigation of the user-friendliness of the implemented models (Chi *et al.,* 2012). In problems related to time and cost overruns, aspects of uncertainty regarding the time of activities and the acquisition of resources are important for future research studies (Prayogo *et al.,* 2018).

The extraction of more data is also recommended for better model training and validation, especially in cases where data were limited on the outset (Won *et al.,* 2018). These limitations illustrate that accountability in decision-making is still an issue to be addressed in the development of ML models for construction planning. The reliance on the quality and quantity of the training and validating data, the relative ambiguity in the selection of the related factors that are addressed for each application, and elements of uncertainty that are difficult to be considered and/or quantified, may result in an unbalanced relationship between the level of informative support that a ML model for construction planning can offer to the decision-making construction managers, and the actual results that the decisions of those construction managers will yield in reality. The aforementioned issue is also directly related to the responsibility accepted by construction managers using ML models for construction planning in their action-taking - an issue also illustrated in the aforementioned limitations, but drawing more on the scope of practical application, rather the understanding of the results of such ML models.

While empirical knowledge is still the main driving force in construction management (even when aided by digitalized tools and techniques such as ML), construction managers rely more and more on the automated results of quantitative data- and qualitative information-driven systems (Bilal *et al.,* 2016). However, the past historic knowledge, best practices, and lessons-learned from which such systems extract, process and utilize data for their training and validation, may in several cases approximate the reality of future predictions in a satisfactory manner, but might also fall short on providing solutions for unprecedented bottlenecks, difficulties and/or

potential disasters. Over-relying on and being over-confident about the prediction results of ML models for construction planning, can lead construction managers to shed some of their responsibility for the actions they actually take following their decision-making; in addition, such an attitude could also weaken their criterion and ability for a quick and out-of-the-box thinking for solving paradoxes and wicked problems.

Such paradoxes and wicked problems may not only be project-specific, but also reflect a more generalized situation apparent in the whole organizational structure of e.g. a construction firm; there is thus even less room for non-sharp thinking on the side of construction managers. The two cases explored in more detail, illustrate the implementation of supervised and unsupervised ML for aspects of construction planning, and build on an assumption of generalizability, i.e. that construction project success, as well as risk and constructability, can have a relationship of causation (and not only correlation) with a set of generic parameters. However, the mentioned limitations in the generalization of the results of the respective models, still hinder the full deployment of such generic solutions. Therefore, future research should focus, among others, on the tackling of problems in generalization, validation and user interface experience - which will, in turn, address more adequately the issues of accountability in decision-making and responsibility in action-taking for construction managers. Expert knowledge is crucial for knowledge inference in ML models within construction planning, especially in complex elements associated with the concepts of stakeholder collaboration and satisfaction, as well as correlated causes behind project efficiency and productivity. Therefore, and despite the capabilities of ML models in providing valuable assistance as auxiliary tools for construction planning, human reasoning - driven by targeted education, tacit knowledge, accumulated experience, and taking-up of current and future challenges in an emergent manner - should continue being cultivated and relied upon. ML models for construction planning should be decision-making helpers, not the decision-makers.

CONCLUSIONS

The implementation of machine learning (namely, systems that algorithmically "learn" by themselves and form predictive systems based on existing datasets) within the construction context, and especially for construction planning, is expected to become even more pronounced in the near future, also following the paradigm shift of digitalisation in construction. As construction projects tend to be influenced by interrelated issues resulting in cost and/or time overruns and lower performance, there has been a continuous attempt to mitigate such issues by developing predictive construction planning systems. ML can offer such a capability. In this research effort, and after a targeted literature review investigating possible applications of ML for construction planning, as well as a more detailed exposition of two application and development cases, certain deductions and identified limitations led to a discussion addressing the issues of responsibility in action-taking, accountability in decision-making, and the still crucial need for human reasoning when it comes to construction managers using such ML systems. Accountability in decision-making may be hindered by the reliance on the quality and quantity of the training and validating data, the relative ambiguity in the selection of the related factors that are addressed for each application, and elements of uncertainty that are difficult to be considered and/or quantified. Such hindrance can result to an unbalanced relationship between the level of support that a ML model can offer to the decision-making construction managers, and the actual results that the decisions of those construction managers will yield in

reality. Also, and through a more practical lens, the responsibility accepted by construction managers using ML models for construction planning in their action-taking, can be affected. Construction managers still rely heavily on their empirical knowledge (even when aided by digitalized tools and techniques such as ML), but also draw more and more on the automated results of quantitative data- and qualitative information-driven systems. However, such systems, however satisfactory their general approximation of the reality of future predictions is, may still fall short on providing solutions for unprecedented situations.

Over-reliance on and being over-confident in the prediction results of ML models for construction planning, can lead construction managers to shed some of their responsibility for the actions they actually take following their decision-making; in addition, their ability for a quick and out-of-the-box thinking for solving paradoxes and wicked problems may be weakened. Furthermore, experience is crucial for knowledge inference in ML models within construction planning, especially in complex elements associated with the concepts of stakeholder collaboration and satisfaction, as well as correlated causes behind project efficiency and productivity; the assumption of generalizability of the prediction results is centrally tied to this knowledge inference process, as the actual applicability and utility of such generalizations can be linked to the reasoning of the construction manager and user of the respective ML system.

As a continuation of the current work, there should be a conduct of research focused on tackling problems in generalization, validation and user interface experience - which will, in turn, address more adequately the issues of accountability in decision-making and responsibility in action-taking for construction managers. In addition, empirical research can be conducted, to address the impact of the such issues in practice and investigate the interfaces between data-driven methodologies used in the training and validation of ML models for construction planning, and the cognitive processes followed by construction managers in their reasoning and problem-solving. As a general conclusion, it is not enough to include human knowledge inference aspects in ML modelling; it is also crucial to strengthen qualified reasoning in the decision-making and accountable action-taking for construction project planning.

REFERENCES

Bilal, M, Oyedele, L O, Qadir, J, Munir, K, Ajayi, S O, Akinade, O O, Owolabi, H A, Alaka, H A and Pasha, M (2016) Big Data in the construction industry: A review of present status, opportunities and future trends, *Advanced Engineering Informatics*, **30**(**3**), 500-521.

Bryman, A and Bell, E (2011) *Business Research Methods*. Oxford: Oxford University Press.

Chan, A P and Chan, A P (2004) Key performance indicators for measuring construction success, *Benchmarking: An International Journal*, 11(**2**), 203-221.

Chi, S, Suk, S J, Kang, Y and Mulva, S P (2012) Development of a data mining-based analysis framework for multi-attribute construction project information, *Advanced Engineering Informatics*, 26(**3**), 574-581.

Creswell, J W and Clark, V L P (2011) *Designing and Conducting Mixed Methods Research 2nd Edition*, Los Angeles: SAGE Publications.

Forbes, L H and Ahmed, S M (2010) *Modern Construction: Lean Project Delivery and Integrated Practices*. Boca Raton: CRC Press.

Kaplan, A and Haenlein, M (2019) Siri, Siri in my Hand, who's the Fairest in the Land? On the Interpretations, Illustrations and Implications of Artificial Intelligence, *Business Horizons*, 62(**1**), 15-25.

Jordan, M I and Mitchell, T M (2015) *Machine Learning: Trends, Perspectives and Prospects*. Science, 349(6245), 255-260.

Kifokeris, D and Xenidis, Y (2018) Application of linguistic clustering to define sources of risk in technical projects, *ASCE-ASME Journal of Risk and Uncertainty in Engineering Systems, Part A: Civil Engineering*, 4(**1**), 04017031-1 - 04017031-13.

Kifokeris, D and Xenidis, Y (2019a) Risk source-based constructability appraisal using supervised machine learning, *Automation in Construction*, 104, 341-359.

Kifokeris, D and Xenidis, Y (2019b) The RISCONA system: Constructability appraisal through the identification and assessment of technical project risks sources. *In: IABSE Symposium Guimarães 2019 Report, Vol 114*, Zurich: International Association for Bridge and Structural Engineering, 1696-1703.

Koch, C and Lundholm, M (2018) *Produktivitetsläget i svensk byggande 2014: Lokaler, Grupphus och Anläggning*, Gothenburg: SBUF.

Liu, X, Song, Y, Yi, W, Wang, X and Zhu, J (2018) Comparing the random forest with the generalized additive model to evaluate the impacts of outdoor ambient environmental factors on scaffolding construction productivity, *Journal of Construction Engineering and Management*, 144(**6**), 04018037.

Lu, P, Chen, S and Zheng, Y (2012) Artificial intelligence in civil engineering, *Mathematical Problems in Engineering*, 1024-123X.

Mahfouz, T and Kandil, A (2011) Litigation outcome prediction of differing site condition disputes through machine learning models, *Journal of Computing in Civil Engineering*, 26(**3**), 298-308.

Portugal, I, Alencar, P and Cowan, D (2018) The use of machine learning algorithms in recommender systems: A systematic review, *Expert Systems with Applications*, 97(**1**), 205-227.

Prayogo, D, Cheng, M Y, Wong, F T, Tjandra, D and Tran, D H (2018) Optimization model for construction project resource levelling using a novel modified symbiotic organisms search, *Asian Journal of Civil Engineering*, 19, 625-638.

Wauters, M and Vanhoucke, M (2014) Support vector machine regression for project control forecasting, *Automation in Construction*, 47, 92-106.

Whittaker, M, Crawford, K, Dobbe, R, Fried, G, Kaziunas, E, Mathur, V, West, S M, Richardson, R, Schultz, J and Schwartz, O (2018) *AI Now Report 2018*, New York: New York University.

Witten, I H, Frank, E, Hall, M A and Pal, C G (2016) *Data Mining: Practical Machine Learning Tools and Techniques*. Burlington, Mass: Morgan Kaufmann.

Won, D, Park, M W and Chi, S (2018) Construction resource localization based on UAV-RFID platform using machine learning algorithm. *In: 2018 IEEE International Conference on Industrial Engineering and Engineering Management*, 1086-1090.

Zhou, J, Love, P E, Wang, X, Teo, K L and Irani, Z (2013) A review of methods and algorithms for optimizing construction scheduling, *Journal of the Operational Research Society*, 64(**8**), 1091-1105.

PUBLIC INFRASTRUCTURE

THE ROLE OF PROJECT SPONSORS IN DEFINING AND REALISING PROJECT BENEFITS

Alex Opoku[1] and Alexander Tallon

UCL Bartlett School of Construction and Project Management, 1-19 Torrington Place, London WC1E 7HB, UK

Sponsors are charged with championing projects in organisations to create value in line with organisational strategy. Analysis of project benefits management enables the business to understand opportunities for improvement and provide a theoretical understanding of the issues faced when large public sector organisations implement the sponsor role. The study examines how the sponsor defines project benefits, aligns them with organisational strategy and ensures they are delivered. The paper presents the results of a Case study involving a major public sector organisation in the United Kingdom with qualitative data collection through interviews with 14 sponsors across the business. The results show that, the sponsor's role is to define, manage and deliver project benefits in line with an organisations strategy. It also confirms that sponsors must be empowered and held to account in order to create meaningful value for an organisation. No business can survive without creating value for customers, and therefore project sponsorship is an essential function of organisations. Even though the research is based on one case study organisation, the result is applicable to other large client organisations, government departments and local authorities in attempt to improve their sponsorship functions.

Keywords: project sponsor, benefits management, organisational strategy

INTRODUCTION

Organisations define strategies that chart how they compete for business and deliver value for customers, using their business model to facilitate this (DaSilva and Trkman, 2014). The strategy development process of an organisation can take a prescriptive or emergent approach, and this will affect the way in which the organisation is able to respond to challenges and opportunities that it faces (Lynch, 2006). The chosen strategy that an organisation follows must align with the market that it is competing in, and whether it wants to lead in product innovation or cost (Porter, 1980). Depending on this decision an organisation will complete projects, which are unique endeavours undertaken in order to create value, in line with their strategy. Research has identified that there are a wide range of change activities and projects needed by organisations, each requiring a unique approach to delivery (Morris and Pinto, 2004). Organisations need to ensure that completed projects deliver benefits aligning to the strategy. Benefits management processes have been proposed in order to align project and strategic objectives; the aim of these processes is to ensure that value is created effectively (Melton, *et al.,* 2011). If value is not created effectively shareholders may dismiss and replace a firm's board, or a firm may be subject to a hostile takeover.

[1] alex.opoku@ucl.ac.uk

Opoku, A and Tallon, A (2019) The Role of Project Sponsors in Defining and Realising Project Benefits *In:* Gorse, C and Neilson, C J (Eds) *Proceedings of the 35th Annual ARCOM Conference,* 2-4 September 2019, Leeds, UK, Association of Researchers in Construction Management, 710-719.

Privatisation is a possible outcome for public bodies that fail to create cost effective value for stakeholders. In each of these scenarios, projects are critical in ensuring organisational survival.

Organisations are not always successful at delivering their strategies; and Pellegrinelli and Bowman (1994) analysed this and identified a common reason: senior management define organisational strategy but leave junior staff to deliver change initiatives (projects) that align to the strategy (Pellegrinelli and Bowman, 1994). In order to ensure that projects deliver benefits that align with strategy some organisations have invested in project sponsorship. The role of the sponsor has been researched and defined by various authors, including Bryde (2008) who identified the role of the sponsor as; to act as the client's representative for the project (Bryde, 2008). The organisation has a sponsorship function to align investment with the core business strategy and ensure that an internal client role is present to champion every project.

LITERATURE REVIEW

Strategy is the direction that a firm chooses to follow in order to create value for customers and gain competitive advantage whilst doing so. Porter's (2001) second principle clearly links strategy to benefits that a firm deliver, a fundamental link that this research explores. However, the fifth principle is important to consider because it demonstrates how strategy links all parts of a firm together, and this is important to remember when considering the role of the sponsor (Porter, 2001). This principle is confirmed by other scholars and has been enhanced by DaSilva and Trkman (2014) who introduced the concept of dynamic capabilities as linking a firm's business model and strategy: defining all three key terms as different time scale perspectives for a firm (DaSilva and Trkman, 2014). Strategy development is often completed by firms and then used to define their business model. The strategy definition process is normally completed in a prescriptive or emergent manner, depending on the organisation involved (Lynch, 2006). However, the process can be completed in a manner that is a combination of the two spectrum extremes; Prescriptive strategy development and Emergent strategy development. Prescriptive strategy development is a classical method that firms employ, involving senior managers determining priorities and imposing a business model and capabilities on the firm in order to meet the defined goals (Lynch, 2006). Mintzberg (2003) considers prescriptive strategy development to be an inflexible and non-linear process that is not adaptive to changes in markets. Emergent strategy development has become more common and is defined as bottom up and people-led strategy definition within an organisation; often it involves staffs who are not senior managers and facilitates flexible changes in dynamic markets (Moore, 2006). It is sometimes defined as being without a-priori intentions (Burnes, 2004) and this can make it a challenge to incorporate in large organisations because of the long-time scales require to change course. Wherever the strategy development process of an organisation is on the spectrum between prescriptive and emergent; it often has to be delivered and realised through planned and prescriptive change initiatives called projects.

Defining the role of the Sponsor

Project management has often focused on delivering a project to the correct cost, quality and schedule (Winch, 2010); it does not focus on ensuring that the correct project is delivered by an organisation in order to deliver its strategy. This is where the role of the sponsor has been developed to ensure that an organisation completes

the right projects. In the prescriptive model of change management, senior management develop and write organisational strategy (Lynch, 2006). This is implemented by client functions within the business, a role that can be considered equivalent and synonymous with that of a sponsor (Pellegrinelli and Bowman, 1994). Bryde (2008) reviewed several definitions from scholars and professional industry bodies and defines the role as the critical risk taker for a project "responsible for activities that span across the whole of the project lifecycle", (Bryde, 2008:801) including the framework of activities identified in Table 1.

Responsibilities of sponsors
1. Define the business benefits/requirements
2. Establishing a project strategy with priorities
3. Agree the project definition, including objectives
4. Define the project success criteria
5. On-going monitoring of the project's business environment and of benefit realisation
6. Taking delivery of a project at completion and, in extreme cases, taking the decision to cancel a project

Table 1: Responsibilities of project sponsors (adapted from Bryde, 2008:801).

Wright (1997) described the sponsor role using the term Project Champion and the term Owner has also been used (Winch and Leiringer, 2016). Therefore, reviews of the role and responsibilities of the sponsor must be cognisant of the plethora of terminology that relates to the role. The key role for the sponsor is to create projects that deliver changes to meet the business's strategy; however, the role is then to allow others to manage and deliver the projects effectively, whilst maintaining an oversight role (Sense, 2013). The sponsor must take ownership of the project after the delivery is complete to measure the effectiveness of the scheme at meeting the defined objectives. However, a challenge for the role of sponsor is the principal agent problem. Communication is fundamental to the role; however, hidden action and asymmetry of information could easily occur between senior management and the sponsor, or between the sponsor and stakeholders and project management professionals (Turner and Müller, 2004). Some organisations have tried to address these challenges by using lesson learnt systems, technology and frequent reporting, but these have disadvantages including cost, administration effort and reliability.

The importance of having a project sponsor has been recognised by the private sector as well. Analysis by KPMG (2017:18) identified it as the "difference between success and failure" of a project. This report identified key roles for the sponsor and these are in line with those that other academics have suggested, whilst adding a stakeholder management role as: "leading the project selection process, defining requirements and benefits that encompass the vision in measurable deliverables, linking projects to organisational strategy, liaising with stakeholders and advocating the project" (KPMG, 2017:20).

Project success factors

The success of a project can be measured in different ways: success criteria are metrics that an organisation defines to judge whether an initiative or the organisation itself has been successful in meeting its goals. It can be financial, rates or performances related but are fixed with a boundary to pass in order to demonstrate success and are commonly linked for projects to the iron triangle of cost, time and quality (Cooke-Davies, 2002; Winch, 2010). Success factors are similar; the presence

of them indicates that an initiative is likely to succeed in meeting an organisation's objectives. The project sponsor/owner has specific tasks in projects and Winch and Leiringer (2016) develop a framework of owner project capabilities as presented in Table 2.

Sponsor/Owner Project Capabilities		
Strategic capabilities	Commercial capabilities	Governance capabilities
Project selection	Packaging	Assurance
Project mission definition	Contracting	Project coordination
Capital raising	Relational	Asset integration
Stakeholder managing		
Project portfolio managing		

Table 2: Owner project capability Framework (adapted from Winch and Leiringer, 2016:273)

Project benefit realisation

Benefits are the incremental improvements that firms create to add value (Zwikael and Smyrk, 2011); in private business this is shareholder value, whereas in the public sector it is often social benefit. Benefits can be tangible or intangible and are broadly defined in the project sector as "a measurable advantage owned by a group of stakeholders incurred by changing the current state through project management mechanisms" (Badewi, 2016:763). Benefits are used by organisations to fill the gap in value between what is present today and what is required to deliver the strategy (Kaplan and Norton, 2008). The importance of benefits in relation to projects is clear and the management of benefits is therefore crucial to the success of projects. Benefits management is defined as "initiating, planning, organising, executing, controlling, transitioning and supporting of change in the organisation and its consequences as incurred by project management mechanisms to realise predefined project benefits" (Badewi, 2016:763). Analysis of the effectiveness of an organisation's benefits management processes can be completed by comparing it to four competences collated by Ashurst *et al.,* (2008); planning, delivering, reviewing and exploiting. Benefits management processes must operate alongside project management to deliver shareholder value or social benefits. Benefits management has been identified as a critical project success factor, especially when benefits management processes are embedded in corporate governance (Serra and Kunc, 2015).

RESEARCH METHODOLOGY

The study adopts interpretivist research philosophy since research into the application of project sponsorship activities is difficult to complete quantitatively despite the theoretical frameworks for responsibilities of the sponsor. Therefore, a qualitative research method has been chosen to analyse the activities that sponsors complete in the case study organisation. The case study organisation is a public sector firm formed in the early 2000s with four business areas supported by professional service functions. A qualitative method of research acknowledges the multiple realities that may be observed throughout the process (Quinlan *et al.,* 2014).

Primary data collection is through semi-structured interviews with sponsors in three business areas within the case study organisation; each business area in the organisation has unique projects, challenges and stakeholders. The number of interviewees required before reaching saturation was determined to be 12 following

analysis by Guest (2006); however, this has been challenged by other scholars including Francis *et al.,* (2014) who proposed that 14 individuals were required. The interview data was analysed using qualitative content analysis. This is a detailed process, initially involving extensive immersion in the interview data, followed by a process of coding and grouping responses by themes (Fellows and Liu, 2003).

RESULTS AND ANALYSIS

The interview sample consists of 14 sponsors from three different business areas of the organisation. This provides a comparison of how projects and benefits are defined, aligned and realised across the organisation. The interviewees are involved greatly with projects and less responsibility for management; this is to ensure that they are focused on projects and value creation within the business. A profile of the interviewees is presented in Table 3.

Interviewee	Role	Type of project	Years of experience
A	Sponsor	Other	3 - 4
B	Principal Sponsor	Highways	3 - 4
C	Principal Sponsor	Highways	5 - 10
D	Sponsor	Highways	3 - 4
E	Sponsor	Other	3 - 4
F	Sponsor	Highways	3 - 4
G	Principal Sponsor	Stations	20+
H	Principal Sponsor	Railway	3 - 4
I	Principal Sponsor	Stations	3 - 4
J	Principal Sponsor	Stations	20+
K	Sponsor	Railway	3 - 4
L	Principal Sponsor	Railway	5 - 10
M	Principal Sponsor	Railway	3 - 4
N	Sponsor	Other	3 - 4

Table 3: A profile of the interviewees

Understanding the organisational strategy

There were multiple ways identified by sponsors for how projects are aligned with strategy. A key document identified to assist with this task is the business case, which records monetised scheme benefits and the links to strategy. The results show that sponsors take the responsibility of defining scheme benefits seriously by using business-wide metrics and aligned with weighted measurable needs as appropriate for the business and customer's requirements: "I weight some priorities higher than others in line with strategy" (Interviewee I).

However, whilst recognising the importance of aligning benefits with strategic priorities, some interviewees discussed how it is more common to align requirements instead of benefits with strategy. Another interviewee stressed the challenges of working in a political organisation: "It can be difficult to define and align benefits (with strategy) when the Government define scheme requirements" (Interviewee C).

The sponsor has the responsibility of establishing project strategy, however, several sponsors found this task challenging to complete for various reasons: these included third party funding limiting the influence the sponsor can have on the scheme, as well

as the highly political nature of the work when negotiating priorities of organisation and the other stakeholders. However, an interviewee working on a third party funded project emphasised how the sponsors had created a 'strap line' which embodies their strategy, demonstrating that even in the intense political environment sponsors can complete this task.

Defining project success criteria

A crucial part of the project definition and alignment process is to establish success criteria. Sponsors completed this using standardised metrics within their business area, like journey time reliability. The study shows that sponsors are accountable for the definition, management and review of success criteria throughout a project's life-cycle; ensuring that the metrics used link to the organisational strategy. The metrics used to define project success were broadly in line with the traditionally defined hard success criteria that form the iron triangle. This was embedded in the business by the requirements management processes and board reviews utilising standardised metrics. However, there is also a focus on more holistic and long-term metrics like value and success factors, using the term 'benefits' to define their project success indicators. Some sponsors admitted only collecting the data required to either update their business case or pass a stage gate review, as required by internal processes. Interviewee 'N' commented that; "Benefits are often bespoke and scheme specific to ensure they are binary, clear and repeatable after a scheme's implementation" (Interviewee N).

The process to collect and define benefits was identified to be the responsibility of the sponsor; but data may be collected by internal or external parties, either as part of business as usual or on an ad-hoc basis.

Aligning project benefits with strategy

Multiple tools are used by the organisation to define and manage benefits and ensure they align with strategies. These include quantitative and qualitative methods such as a business case, project requirements statement and benefits management plan etc. The benefits management plan was identified as the document aligning benefits to strategy best, but also as being "very complex, leading to caring about cost, quality and time on a day to day basis" (Interviewee H). The metrics collected to define and assess project benefits were frequently discussed to be quantitative, standardised and linked to organisational strategy, like success criteria. Interviewees didn't believe there is a standardised process and felt unsupported due to working in a small team as stated by interviewee 'H'; "There is a very unclear process to defining and aligning benefits (in respect to strategy)".

The approach to benefits definition was identified as defined at programme level and not organisation or business wide. One interviewee stated that benefits are "mainly valuable later" (Interviewee M). This comment indicates the process isn't successful in their business area, and if the planning competence is not effectively delivered it will be difficult for the organisation to deliver later competences. The process to select projects which best meet organisational needs when limited funds are available was investigated. Boards often decide how to proceed, and the decision can be driven by political influence as well as by comparing project benefits. Interviewee 'A' referred to a workshop prioritisation process and assessment using criteria defined at programme level. Corporate sponsors identified a Multi-Criteria Assessment framework used to define and assess projects and options. Sponsors agreed that qualitative comparisons lead to better, customer-focused decisions.

The sponsor's role in benefits realisation

Sponsor's role during the initiation project phase is to define clear goals for projects, in some cases using processes like benefits mapping. Sponsors ensure projects realise benefits by maintaining regular communication, defining clear aims and requirements and "ensuring the problem is fully understood prior to identifying solutions" (Interviewee B). There is an important role for sponsors to ensure that benefits are realised throughout the lifecycle of the project; stage gate reviews, project boards and the change control process were identified as critical to review benefits. Interviewee 'J' argued that; "Stakeholders propose changes and the role of the sponsor is to review the change in line with the impact it may have on the benefits of the scheme" (Interviewee J).

One sponsor described his role as an "active team player managing stakeholders and understanding issues" (Interviewee N) thus enabling him to protect scheme benefits. Some sponsors commented that the quick move to new projects after delivery means benefits realisation doesn't get completed fully.

Sponsors proactively take responsibility for monitoring project outcomes during construction and post construction, comparing the results with pre-scheme data on benefit realisation. Moreover, there is an internal benefits support team as part of the Project Management Office to provide guidance, and on some projects "contractor benefit analysis is written into the project contract" (Interviewee M). The timescale after which benefits are realised can vary depending on the nature and the project's relationship with other interlinked and non-linear programme investments. In some cases, data is not available for at least 3 years after project completion, and for large scale projects, 10-year frameworks may be more realistic if wider scheme effects are to be included. The benefits realisation phase also demonstrated a principal agent problem where there is the tendency by sponsors to only report and amplify good/positive news. This is mostly done in order to secure further programme funding for future schemes.

In terms of how information/data is collected during benefits realisation, it was noted that the benefits process contrasts with the lessons learnt process, which is managed using a centrally recorded portal. Some local project reporting tools existed in some parts of the business but did not feed into a central system. The project close-out report was the only compulsory document identified by sponsors to record this information in a qualitative manner, but this doesn't the business to map project completion to organisational objectives. For example, interviewee 'M' commented that; "Data on benefits from most projects is not centrally captured, but likely to be saved on local team shared drives".

Again, the business tends to focus mainly on the delivery of outputs and not benefits, as noted by interviewee 'G'; "benefits realisation is not championed by senior managers, and therefore it doesn't happen".

DISCUSSIONS

A firm's strategy and the strategy development process define the need for firms to complete projects and change initiatives. The strategy development process of the case study organisation has been identified as prescriptive. Sponsors have a clear understanding of organisational strategy and use multiple tools to align projects with strategies. It has been confirmed that sponsors are involved in defining project success criteria but harder to implement when third party funding is supporting a

project. However, corporate sponsors have less responsibility to define success criteria because other project teams set clear objectives. The study shows that business areas in the organisation do have processes to manage project benefits realisation. The sponsor has a role of keeping the strategic capabilities of owners. The benefits management processes have local variations and aren't centralised. Some variations are effective at managing benefits, and some internal project management methodology documentation is best suited to larger projects. To improve benefits management processes, the organisation needs to recognise its value and harmonise processes. The case study organisation has an effective sponsorship function that links the responsibilities to the strategic capabilities of strong owners. The project sponsor's role is to define, manage and deliver project benefits in line with an organisation's strategy. Project sponsors must be empowered and held to account in order to create meaningful value for an organisation.

CONCLUSIONS

Benefits realisation throughout the life-cycle of in-flight projects was also considered and benefits were mainly found to be managed and protected using the change control and gate review processes, which are mandatory across all business areas in the organisation. Other formal documentations and reviews required by internal project management methodology and assurance reviews, led to benefits management tasks being completed. For projects post-completion, the benefits realisation process was managed in different ways depending on business area. Depending on the details available from a project's definition phase, sponsors generally complete benefits realisation, but this depended on time availability. The methods that sponsors use to define and align project benefits were uncovered to include internal project management methodology documentation and the Project Overview Plan for smaller projects. The benefits alignment process varied according to business area but aimed to link to both the organisation's strategy and local business plans.

More success at completing benefits realisation was observed when future programme funding relied upon data from current schemes. Several methods of managing benefits were observed across the business and several were identified; the benefits management culture in the organisation was found to be well embedded, supported by standardised documentation. This is partly believed to be because the sponsors look after fewer larger projects and therefore have more time to follow the processes required. However, to improve the quality of benefits management, a formal benefits realisation for each project should be adopted. Senior management should create a culture that focuses on value creation by ensuring project delivery success criteria observe the wider benefits.

REFERENCES

Ashurst, C, Doherty, N F and Peppard, J (2008) Improving the impact of IT development projects: the benefits realization capability model, *European Journal of Information Systems*, 17(**4**), 352-370.

Badewi, A (2016) The impact of project management (PM) and benefits management (BM) practices on project success: Towards developing a project benefits governance framework, *International Journal of Project Management*, 34(**4**), 761-778.

Bryde, D (2008) Perceptions of the impact of project sponsorship practices on project success, *International Journal of Project Management*, 26(**8**), 800-809.

Burnes, B (2004) Emergent change and planned change - competitors or allies? *International Journal of Operations and Production Management*, 24(**9**), 886-902.

Cooke-Davies, T (2002) The real success factors on projects, *International Journal of Project Management*, 20(**3**), 185-190.

DaSilva, C. M and Trkman, P (2014) Business model: What it is and what it is not, *Long Range Planning*, 47(**6**), 379-389.

Fellows, R F and Liu, A M (2003) *Research Methods for Construction, 2nd Edition*. Oxford: Blackwell Science.

Francis, J J, Johnston, M, Robertson, C, Glidewell, L, Entwistle, V, Eccles, M P and Grimshaw, J M (2010) What is an adequate sample size? Operationalising data saturation for theory-based interview studies, *Psychology and Health*, 25(**10**), 1229-1245.

Guest, G, Bunce, A and Johnson, L (2006) How many interviews are enough? An experiment with data saturation and variability, *Field Methods*, 18(**1**), 59-82.

Kaplan, R S and Norton, D P (2008) *The Execution Premium: Linking Strategy to Operations for Competitive Advantage*. Boston, USA: Harvard Business Press.

KPMG (2017) *Driving Business Performance*. Wellington, New Zealand: KPMG.

Lynch, R L (2006) *Corporate Strategy*. Harlow, UK: FT/Prentice Hall.

Melton, T, Yates, J and Iles-Smith, P (2011) *Project Benefits Management: Linking Projects to the Business*. Butterworth-Heinemann.

Mintzberg, H (2003) *The Strategy Process: Concepts, Contexts, Cases*. Harlow, UK: Pearson education.

Moore, J F (2006) Business ecosystems and the view from the firm. *The Antitrust Bulletin*, 51(**1**), 31-75.

Morris, P W and Pinto, J K (2004) *The Wiley Guide to Managing Projects.* Hoboken, NJ: Wiley.

Pellegrinelli, S and Bowman, C (1994) Implementing strategy through projects, *Long Range Planning*, 27(**4**), 125-132.

Porter, M E (1980) Industry structure and competitive strategy: Keys to profitability, *Financial Analysts Journal*, 36(**4**), 30-41.

Porter, M E (2001) Strategy and the Internet, *Harvard Business Review*, 79(**3**), 62-79.

Quinlan, C, Babin, B J, Carr, J C, Griffin, M and Zikmund, W G (2014) *Business Research Methods*. Andover, UK: Cengage Learning.

Sense, A J (2013) A project sponsor's impact on practice-based learning within projects. *International Journal of Project Management*, 31(**2**), 264-271.

Serra, C E M and Kunc, M (2015) Benefits realisation management and its influence on project success and on the execution of business strategies, *International Journal of Project Management*, 33(**1**), 53-66.

Turner, J R and Müller, R (2004) Communication and co-operation on projects between the project owner as principal and the project manager as agent, *European Management Journal*, 22(**3**), 327-336.

Winch, G M (2010) *Managing Construction Projects, 2nd Edition*. Oxford: Wiley-Blackwell Publishing.

Winch, G M and Leiringer, R (2016) Owner project capabilities for infrastructure development: A review and development of the strong owner concept, *International Journal of Project Management*, 34(**2**), 271-281.

Wright, J N (1997) Time and budget: The twin imperatives of a project sponsor, *International Journal of Project Management*, 15(**3**) 181-186.

Zwikael, O and Smyrk, J R (2011) *Project Management for the Creation of Organisational Value*. London: Springer.

THE EMBEDDING OF THE CONSTRUCTION CLIENT ROLE IN DUTCH MUNICIPALITIES AND ITS EFFECTS ON PROFESSIONALISM AND ORGANISATIONAL LEARNING

Marleen Hermans[1], Hanneke Veldhuis, Denise Huizing and Simone Rots

Faculty of Architecture and the Built Environment, Management in the Built Environment, Delft University of Technology, Julianalaan 134, 2628 BL Delft, The Netherlands

Municipalities account for a considerable share in the total production of construction work in the Netherlands. Through their commissioning role, public entities can act as a 'launching customer' for innovation. New procurement schemes have been and are being installed to improve quality and productivity, reduce risks and enhance sustainability within the industry. The effective application of these schemes requires a professional commissioning organisation, able to consistently adopt and further develop these new schemes. A clear organisational structure and aligned working processes are prerequisite to establish efficiency, effectivity, knowledge management and organisational learning. A qualitative research project investigated the governance structure and embedding of the commissioning role in Dutch municipalities. 18 municipalities were investigated through structured interviews and additional document analysis. The research elucidates the shattering of the commissioning role over the municipal organisation, with limited alignment of processes between entities involved and hybrid organisation structure and governance issued by municipalities show substantial variation and hybridity within the municipal organisations. The allocation of administrative responsibility for complex is not clear-cut, varying with the distribution of political responsibility for related policy areas between various aldermen. Although differences exist between larger and smaller municipalities, overall findings are similar. The fragmentation level found, can be expected to hamper possibilities for organisational learning and improving professionalism. To improve these possibilities, preconditions for knowledge management and organisational learning should be strengthened, starting with stimulating the awareness of the relevance of commissioning role.

Keywords: procurement, public administration, governance, organisational learning

INTRODUCTION

The construction sector has a significant impact on living standards, the capability of a society to produce goods and services, and its capability to trade effectively (Manseau and Seaden 2001). Due to their large share of total construction output, public organisations have a substantial influence on the quality of the built environment and the construction process itself (Vennstrom 2008, Winch 2010).

[1] m.h.hermans@tudelft.nl

Hermans, M, Veldhuis, H, Huizing, D and Rots, S (2019) The Embedding of the Construction Client Role in Dutch Municipalities and Its Effects on Professionalism and Organisational Learning *In:* Gorse, C and Neilson, C J (Eds) *Proceedings of the 35th Annual ARCOM Conference,* 2-4 September 2019, Leeds, UK, Association of Researchers in Construction Management, 720-729.

In the Dutch construction industry, municipalities account for the majority of public tendering activity (Stichting Aanbestedingsinstituut, 2015). From a social responsibility viewpoint, public clients are expected to actively contribute to innovation and improvement of this sector and work as effectively and efficiently as possible (Beck Jørgensen 1999, Boyd and Chinyio 2006, Manley 2006, Ye *et al.,* 2014, Hermans *et al.,* 2018). Over the last twenty years, new public-private arrangements, often performance based, rapidly evolved, as a part of construction sector reform and boosted by societal challenges such as sustainability, citizen participation, and the need for cost and risk reduction. A still developing kaleidoscope of project delivery models being one of the results. In order to keep up with the changes and enable adequate implementation of all these new arrangements, public organisations, such as municipalities, need to be able to adapt and learn. Finger (1999), however, indicates that learning within public organisations is more difficult than in private organisations due to the complexity of the environment in which public organisations operate. Furthermore, Volker (2018) argues that in a project-oriented context, such as the construction domain, organisational learning is even more difficult. Nevertheless, Hermans *et al.,* (2016) underlines the importance of a coherent approach towards commissioning as new types of collaboration require adapted governance structures, competences, knowledge and instrumentation. Municipal organisations currently often lack this coherent approach (Hermans and Eisma 2015).

Compared to other public organisations, the municipal construction practice encompasses a wide range of segments: real estate (offices, schools, sports accommodations), infrastructure (roads, waterways, energy networks), and public space. The commissioning role within municipalities is multifaceted, possibly impeding a consistent approach. Expectations are that learning in the construction sector might be even more challenging for municipalities than for other public entities.

RESEARCH OBJECTIVE

Although the importance of public organisations in the construction industry and their responsibility in commissioning has been recognized in literature, the understanding of the actual nature and configuration of public commissioning is limited and data collection remains fragmented (Hermans *et al.,* 2016). To increase the professionalism of construction clients and enable them to change, strengthening their learning capacities is prerequisite. To effectively and efficiently build, collect, secure and implement new knowledge attached to new ways of commissioning, insight in where and how tasks attached to the commissioning role are embedded within the organisation is prerequisite, as a starting point, to facilitate future change. Patrucco *et al.,* (2018), however, draws attention to the lack of research into the organisational aspects of public procurement, and claims that this field is still relatively new and lags behind private procurement literature.

Therefore, a research project was started to gain insight in the current positioning of the commissioning role and the related tasks in Dutch municipalities, answering two research questions: How is the commissioning role embedded and governed in Dutch municipal organisations? And how do these structures influence the possibilities for professionalizing the commissioning role?

Theoretical Background

Each construction activity within the public domain requires outsourcing, whether it be consultants, architects, engineers, contractors or other parties within the supply chain. Commissioning work is a common part of construction activity of any public organisation (Hermans 2014, Winch 2010). The positioning of the commissioning role can be expected to be related to the organisational structure used for the municipality as a whole.

The commissioning role and the municipal organisation structure

Johnston (2015) gives a well-recognized description of a public administration, changing from a traditional practice, with a clear separation between political and administrative powers under the influence of New Public Management (NPM), towards a more service oriented organisation based on performance thinking, and, inspired by NPM, towards a network organisation type where enlarging public value becomes the main objective (Johnston 2015, Meyer and Leixnering 2015).

Aardema and Korsten (2009) present a typology of organisation structures applied within the Dutch municipalities, closely resembling these international developments. Their typology contains a secretary model, representing the traditional model, a sector and a service model. Within the secretary model, primarily applied in the 80s, policy making, and execution are separated, and supporting functions (such as finance and control) are centralised. Due to competition between the secretary role (strategy and standardization) and the execution (operating core), municipalities shifted towards the sector model. In the sector model policy making and execution are combined and supporting functions are decentralised in departments focussing on specific policy areas ('sectors'). Dissatisfaction regarding compartmentalisation caused yet another shift to be made towards the service model. In this model both policy making, execution and supporting functions are organised in departments, and more focus is put on output rather than policy areas. Additionally, executive work was increasingly transferred to the private sector (Aardema 2005), a process also depicted by (Johnston 2015). A fourth model is an optimised form which can be recognised as the network model and is closely related to Mintzberg's (1989) 'adhocracy', where mutual adjustment is key (Aardema 2005).

Commissioning and Sectors Within the Municipal Context

Johnston (2015) and Meyer and Leixnering (2015) also describe the internal consequences of the change due to NPM, noting the separation of distinctive functions such as policy making, regulatory tasks, supervision, commercial tasks and operational services, and portray an increased outsourcing of service provision. Mintzberg (1989) states that an organisation can be defined by the interplay of five interdependent parts: the strategic apex, the operating core, the 'middle line' in between this strategic and operational part, a 'techno structure' focussing on standardization of the primary operational processes, and a supporting staff for all secondary functions.

In a municipal context, owning and developing assets is an enabler in policy processes, rather than a prime goal. The way municipalities organise and embed the asset management role, depends on and will be a derivative of the municipality's main structure, but will also depend on the way the municipality looks upon its role in the different segments of construction.

Using Mintzberg's view on organisational structures, the commissioning role could be positioned in various ways within a municipality: if real estate is viewed upon as an accommodation facility, it may be seen as part of the supporting staff. On the other hand, providing infrastructure and public space is appreciated as a prime task of municipality, and thus related commissioning activity will be seen as a part of the operating core. However, from the viewpoint of commissioning as a procurement function, it may also be seen as a part of the organisation's techno-structure, as a standardized supporting function, or a part of the supporting staff if standardization is not a key issue.

From these different viewpoints, the commissioning role can be positioned in various places within the municipal organisation. The embedding of the commissioning role might also alter between sectors, when ideas on the role of real estate might differ from those of infrastructure or public space within the policy making process.

Activities Within the Commissioning Role

Murray (2009) describes the commissioning cycle with a continuous flow of tasks consisting of strategic needs assessment, deciding priorities and outcomes, planning and designing services, options appraisal, sourcing, delivery, and monitoring and review. He identifies purchasing as the process of choosing and selecting suppliers, covered in the 'sourcing' phase in his cycle and suggests procurement encompasses purchasing but also the more strategic pre-purchasing 'make or buy' decision (Murray 2009: 199).

As defined by Bang (2017: 14), in line with the commissioning cycle drawn by Murray, commissioning refers to "the way an organisation, in relation to its responsibilities in the built environment, shapes and implements its interaction with the supply market both externally and internally. Commissioning covers all activities relating to programming, selecting appropriate project delivery methods, setting the brief, procuring and contracting and contract management related to new construction, and managing the existing stock." This definition incorporates all activities a construction client would do in fulfilling his role, which by Boyd and Chinyio (2006) is defined as being "the initiator of projects and those that contract with other parties for the supply of construction goods and services".

Related to this commissioning role, Hermans (2014) distinguishes the external role for any public construction client that relates to the actual transaction with the supply market, and the internal role, within the client organisation itself, that relates to how the demand to the market is being prepared and processed.

In construction commissioning activities are closely intertwined with project management activity, as project management encompasses a continuous flow of commissioning actions, to consultants, architects, engineers, contractors, suppliers or service providers in each phase of a project or asset management activity. In Murray's cycle this part of commissioning activity would fit within his 'planning and designing' phase (Murray 2009).

At an organisational level, other types of commissioning activity can be recognised, in the organisation's overall sourcing and procurement policy, in producing overall spend analyses, etcetera. The commissioning role therefore consists of a multitude of activities on both an organisational and project level.

Depending on an organisation's sourcing policy and project delivery models chosen, the contents of the given activities will change, and some will even be outsourced

completely. In a mature client organisation, all interrelated tasks are aligned to fit these choices (Hermans *et al.,* 2016). In terms of Murray's cycle: the cycle should be closed and aligned.

RESEARCH METHOD

The study, executed in 2016 and 2017, consisted of a number of qualitative structured interviews among key persons of municipalities. Nationwide, 18 municipalities were selected in three different regions (West, South and North-East). To ensure that the municipalities investigated had a sufficient commissioning portfolio, both in investment as well as in asset management activity, all municipalities counted more than 25.000 inhabitants, in four categories: small-sized (less than 50.000 inhabitants), medium-sized (between 50.000 and 100.000 inhabitants), large-sized (between 100.001 and 250.000 inhabitants) and very large-sized (more than 250.000 inhabitants) (see Figure 1).

	Region North		Region West		Region South	
Size	**Municipality**	**Inhabitants**	**Municipality**	**Inhabitants**	**Municipality**	**Inhabitants**
Very large			Den Haag (3x)	519988		
			Rotterdam (1x)	629.606		
Large	Groningen (1x)	200.952	Leiden (1x)	122.561	Eindhoven (1x)	224.755
	Leeuwarden (1x)	107.897	Delft (1x)	101.034	Tilburg (2x)	212.941
	Zwolle (2x)	124.896				
	Enschede (2x)	158.351				
Middle	Assen (2x)	67.061			Helmond (1x)	90.127
	Hoogeveen –	55.240			Sittard - Geleen (1x)	93.555
	De Wolden (1x)				Roermond (1x)	57.010
Small			Maasluis (1x)	32.292	Middelburg (1x)	47.873
			Krimpen aan den IJssel (1x)	29.054		
(Between brackets): number of interviews						

Figure 1 Municipalities that were part of the research project in 2016 and 2017

The total number of Dutch municipalities being 380, the research in this stage did not aim for a representative picture of the municipalities within each group, but for a first impression of the embedding of the commissioning role and indications of possible differences between the different size categories.

Respondents were chosen on expected overview of municipal commissioning activity. A combination of both political as well as administrative managers was made, including both aldermen as well as directors and department managers. 24 interviews were held, some with a combination of respondents, with a gross total of 29 respondents. The interview protocol covered questions related to the type and quantity of construction-related activity; the political administrative and civil embedding of the commissioning role and governance structures used and; elements for further professionalization of the commissioning role. This paper primarily focusses on the results of the second group of questions.

To ensure reliability of the data all interviews were audiotaped, fully transcribed, checked by the respondent sending them a summary of the conversation, and thematic theoretical coding is applied in Atlas.ti to indicate statements regarding issues such as the positioning of the administrative and political responsibilities, organisational structure, interaction and networking and professionalism. In addition to the interview result, relevant documents describing the municipal organisation and the governance structure of commissioning activities were analysed.

ANALYSIS/RESULTS

Domain of Work

An inventory was made of the extent to which the municipality was involved in either investment projects and/or maintenance and (asset) management activity in different segments of the construction domain. The inventory indicated that all municipalities

execute commissioning work in 'dry' infrastructure (roads, bridges etc.) and in public space. Some have significant investment activities in non-residential building (social property such as schools, community centres), 'wet' infrastructure (water works), utilities and sports and recreation. Some also maintain and manage utility buildings, housing, wet infrastructure and sports and recreational facilities.

One of the remarkable results is that hardly any of the respondents had an overall view of the quantity and nature of commissioning activity in the sum total of sectors mentioned. Given the managerial level of the respondents, this is an indicator for fragmentation in the governance of total commissioning activity.

Functions and Tasks Related to Public Commissioning

Table 1 gives an overview of activities related to the commissioning task. Interviewees were asked whether or not their organisation outsources these activities and where in the municipal organisation the activities are being carried out. The interviews show that even today most municipalities still execute most tasks related to their commissioning role in house, sometimes strengthened, for instance to increase flexibility, by insourcing (see Table 1).

Table 1 Sourcing strategy for commissioning tasks

Task	Sourcing
Commissioning cycle	
Strategy and policy making	Mainly own organisation
Specifying maintenance programs and briefs	Mainly own organisation
Business cases and financial assessments	Partly own organisation, partly outsourced
Budgeting and calculating	Partly own organisation, partly outsourced
Purchasing	Mainly own organisation
Tendering	Mainly own organisation
Project management	Mainly own organisation
Engineering and specialist technical advice	Mainly own organisation
Contract management	Mainly own organisation
Inspection and auditing	Partly own organisation, partly outsourced
Accounting and reporting	Mainly own organisation
Project related activities (construction process specific)	
Application for permits	Mainly own organisation
Real estate transactions	Mainly own organisation
Land transactions	Mainly own organisation
Preparing technical specs	Mainly outsourced
Design Work	Partly own organisation, partly outsourced
Work preparation	Partly own organisation, partly outsourced
Execution (construction / maintenance work)	Mainly outsourced
Site supervision and management	Partly own organisation, partly outsourced

Generally speaking, for large scale projects and specialist activity, municipalities are outsourcing tasks particularly for integrated contracts. Specialist tasks that are outsourced relate to engineering, business cases, preparing specifications and calculating. For most municipalities the share of integrated contracts used was still fairly limited, with design-bid-build still being the prime choice.

The Organisation of Commissioning in Municipalities

Role allocation within the municipal organisation

The municipal council, the mayor and aldermen are the political clients for construction work, bearing the ultimate political responsibility for policy programs and budgets. Deviations from these programs and budgets must always be accounted for in the council. In large municipalities, a number of aldermen is involved, with separate aldermen for urban development and asset management. Real estate typically is organised in yet another department and either appointed to one specific alderman

and a centralised (staff) unit or is allocated to the policy area's (sectors) served; e.g. asset management related to schools to education; sports accommodation and theatres to the sports and culture sectors respectively. Sustainability and other specific policy programmes are often the domain of a dedicated aldermen, as well are large urban planning projects. Large projects often have a supervising alderman, that can be different from the sector.

The administrative top of the municipality is responsible for the implementation of policy programmes in the civil service organisation. Directors or department heads Real Estate, Spatial Planning or Urban development, Urban Management are responsible for managing the real estate portfolio, public space or urban planning. These directors deploy the policy programmes as projects or activities within their departments to their coordinators and project managers. act as

The implementation of projects or management activities is entrusted to project managers. The project managers, depending on their mandate, fulfil the role of external client to the market. The larger, more complex or politically sensitive the project, the higher responsibility is placed within the municipal organisation. Some municipalities have expertise centres such as a project management office or an engineering office. Large and very large municipalities all have these, whereas the smaller ones sometimes collaborate with other municipalities or outsource these tasks.

In the execution of their work project managers closely collaborate with the engineers within the municipalities and with the procurement department. In large municipalities the central procurement departments have a policy making and advisory role to the operating core. In smaller municipalities these departments often have a more operational role.

Smaller municipalities often have simpler structures, with aldermen and heads of department taking care of plural policy areas. Governance structures therefore are much clearer, but combined responsibility requests combined skills and competencies in a limited number of administrators. Furthermore, in smaller municipalities the political top appears to directly interfere more with project execution than the aldermen in large municipalities, who tend to focus more on the overall programmes and very large projects.

Municipal organisational model

The positioning of the commissioning role depends on the organisational model. The analysis of the organisational models and the interviews show that there are many differences between the municipalities. Most municipalities do not have a pure model; most models appear to be hybrid models, combining features of each model mentioned before. Large municipalities use a service, a sector or network model. In very large municipalities, the sector or service model is used most often (see Table 2). More often than not, for some segments the 'services' model is being used, for instance for urban planning and management, while for others, for instance real estate, a sector model is being applied for specific real estate such as schools and sports facilities, while for municipal offices tasks related to real estate are appointed to a part of the supporting staff, for instance facilities management department.

Middle-size and small sized municipalities use a service or a sector model. Both political as well as administrative governance structures are simpler, with only a very limited number of aldermen and combined responsibilities in the administrative top. Different from the large municipalities, these municipalities mention the role of a

procurement department (staff position) more often. Also, project management departments are sometimes shared internally with the social domain. Both the role and positioning of the procurement department differs centralized, decentralized of a combination. And different sectors within one municipality sometimes each have their own solution. The same is true for the project management and engineering offices. A number of medium-sized and small municipalities share an executive organisation for projects or for purchasing.

Table 2 Organisation structure of municipalities with the typology of organisation models of Aardema and Korsten (2009)

Municipality	Size	Organisational structure	Pure model?	Engineering office	Project management office
Groningen	Large	Sector model	Yes	Yes	No
Enschede	Large	Services model	No	No	No
Tilburg	Large	Sector model	No	Yes	No
Zwolle	Large	Sector model	?	?	No
Delft	Large	Network model	Yes	No	No
Leeuwarden	Large	Services model	Yes	No	Yes
Eindhoven	Large	Network model	No	?	No
Leiden	Large	Services model	Yes	No	Yes
Krimpen aan den IJssel	Small	Services model	Yes	Yes	No
Middelburg	Small	Sector model	Yes	Yes	No
Maassluis	Small	Services model	Yes	No	No
Assen	Mid-size	Sector model	No	Yes	No
Helmond	Mid-size	Sector model	?	?	?
Hoogeveen - de Wolden	Mid-size	Sector model	No	?	?
Roermond	Mid-size	Services model	Yes	Yes	No
Sittard-Geleen	Mid-size	Network model	Yes	No	No
Den Haag	Very Large	Services model	Yes	Yes	No
Rotterdam	Very Large	Services model	Yes	Yes	No

The position of the engineering department, project management, procurement or real estate departments and their responsibilities cannot easily be predicted on the basis of the main municipal organisational model. Interviewees working in a municipality with a network model generally have a better picture of the embedding of the commissioning role than those who work in municipalities operating according to a service or sector model. In a municipality with a network model. responsibilities appear to be clearer cut, due to reduced compartmentalisation at departmental level and a clear assigning of roles to a fixed group of people. This eases organisation-wide programmatic management. Commissioning appears to be clear, transparent and strongly embedded in these organisations.

CONCLUSIONS

The organisational model was expected to be an important indicator for the positioning and embedding of commissioning tasks. This assumption proved false for the positioning of the commissioning role within Dutch municipalities. Today, however, municipalities in the Netherlands, appear to be in a transition state and show hybrid organisational structures, combining characteristics of different types of models for different parts of their organisation. As most municipalities use a sector or services model, the commissioning role is decentralised to departments, often per sector, service area or policy domain. Governance structures often differ accordingly.

Fragmentation is very clear in internal commissioning, with a multi-headed political and administrative governance structure. In external commissioning (project and activity related), commissioning tasks are often assigned to project management or engineering departments. For infrastructure and public space, responsibilities are usually clearly assigned to dedicated departments. For real estate, this situation is

quite different: some municipalities have centralized real estate departments, others decentralised entities. The commissioning role does not (yet) appear to be a clearly defined and governed role within municipalities. The found level of fragmentation, combined with this poor definition, and therefore awareness, of the commissioning role, may impede learning processes. Therefore, improving the learning capacity and professionalism regarding the commissioning role in municipal organisations would necessitate a better insight in the specific positioning of this role in a particular municipality. Also, a learning strategy would need to be designed to overcome the current level of fragmentation.

DISCUSSION

Academic theory on the embedding and governance structures of the commissioning role in municipalities is largely missing. This research project has tried to add to this knowledge gap. Its findings, indicating a fragmented structure for the commissioning role, matches the findings of (Christensen 2010: 7) and (Johnston 2015: 9) that public organisations are becoming increasingly complex and hybrid, in their attempts to combine numerous and conflicting structures while trying to implement different generations of public reform. As research on organisational structure in the area of commissioning is limited, further analysis is necessary, particularly in possibilities to improve the current situation or how to effectively organise commissioning given the current hybrid situation within overall municipal governance.

REFERENCES

Aardema, H (2005) Het directiemodel overheids, *Management*, 1, 12-15.

Aardema, H and Korsten, A F A (2009) Gemeentelijke organisatiemodellen - Hoe integraler het moet, hoe minder je het ziet, *In: A* Bekke, C Breed and P de Jong (Eds.) Naar een collegiaal en samenhangend overheidsbestuur Sdu Uitgevers.

Bang, H L, Hermans, M, Simonsen R and Mogendorff K (2017) The merits of client organisations, *In:* K Haugbølle and D Boyd (Eds.) *Clients and Users in Construction: Agency, Governance and Innovation*. New York: Routledge.

Beck Jørgensen, T (1999) The public sector in an in-between time: Searching for new public values, *Public Administration*, 77(**3**), 565-584.

Boyd, D and Chinyio, E (2006) *Understanding the Construction Client*. Oxford: Blackwell.

Christensen, T and Lægreid, P (2010) Complexity and hybrid public administration-theoretical and empirical challenges, *Public Organisation Review*, 11(**4**), 407-423.

Finger, M and Brand, S B (1999) The concept of the 'Learning Organisation' applied in the transformation of the public sector: Conceptual contributions for theory development in organisational learning and the learning organisation *In:* M Easterby-Smith, L Araujo and J Burgoyne (Eds.) *Developments in Theory and Practice*. London: Sage.

Hermans, M (2014) *Is a Little More Alright*? Netherlands: Delft University of Technology.

Hermans, M and Eisma, P (2015) Behind the scenes of public construction clients - Collecting data on commissioning activities and organisational Approach, *Procedia Economics and Finance*, 21, 391-398.

Hermans, M, van Zoest, S and Volker, L (2016) Assessing the Maturity of Public Construction Client Organisations. *In:* Chan, P W and Neilson, C J (Eds.) *Proceedings of the 32nd Annual ARCOM Conference*, 5-7 September 2016, Manchester UK. Association of Researchers in Construction Management, 155-163.

Hermans, M, Veldhuis, H and Huizing D (2018) *Inbedding Van De Opdrachtgevende Rol in Gemeentelijke Organisaties*. Netherlands: Delft University of Technology. Available from https://repository.tudelft.nl/islandora/object/uuid:84ef5c77-fb0f-4b93-9928-c123db899710?collection=research [Accessed 19/07/2019]

Johnston, J (2015) Public administration: Organisational aspects, *In:* J.D Wright (Ed.) *International Encyclopaedia of the Social and Behavioural Science*. Oxford: Elsevier.

Manley, K (2006) The innovation competence of repeat public sector clients in the Australian construction industry, *Construction Management and Economics*, 24(**12**), 1295-1304.

Manseau, A and Seaden, G (Eds.) (2001) *Innovation in Construction - an International Review of Public Policies*. London: Routledge.

Meyer, R E and Leixnering, S (2015) Public sector organisations, *In:* J D Wright (Ed.) *International Encyclopaedia of the Social and Behavioural*. Science Oxford: Elsevier.

Mintzberg, H (1989) *Mintzberg on Management: Inside Our Strange World of Organisations*. New York: Simon and Schuster.

Murray, J G (2009) Towards a common understanding of the differences between purchasing, procurement and commissioning in the UK public sector, *Journal of Purchasing and Supply Management*, 15(**3**), 198-202.

Patrucco, A S, Walker, H, Luzzini, D and Ronchi, S (2018) Which shape fits best? Designing the organisational form of local government procurement, *Journal of Purchasing and Supply Management*, 25(**3**), 100504.

Stichting Aanbestedingsinstituut Bouw and Infra (2015) Veilig Verder, Resultaten Aanbestedingsanalyse 2014. Available from www.aanbestedingsinstituut.nl

Vennström, A (2008) *The Construction Client as a Change Agent: Contextual Support and Obstacles*. PhD Thesis, Luleå University of Technology, Sweden.

Volker, L, Willems, T, Kuitert, L, Van Marrewijk, A and Hermans, M (2018) Cutting and Binding the ties Understanding the influence of project autonomy on project-based learning and innovation, *In: EGOS 2018 34th EGOS Colloquium 2018*, 2 July 2018, Tallinn, Estonia.

Winch, G (2010) *Managing Construction Projects: An Information Processing Approach 2nd Edition*. Oxford: Wiley-Blackwell.

Ye, K, Shen, L, Xia, B and Li, B (2014) Key attributes underpinning different mark-up decision between public and private projects: A China study, *International Journal of Project Management*, 32(**3**), 461-472.

NAVIGATING THE LOGICS OF CHANGING PUBLIC FACILITIES MANAGEMENT

Ingrid Svensson[1] and Martin Löwstedt

Department of Technology Management and Economics, Division of Service Management and Logistics, Chalmers University of Technology, 412 96 Göteborg, Sweden

Growing cities, new governmental sustainability directives, and a large building stock in need of acute measures put pressure on public facilities management organizations to transform their operations. However, the complex organizational context encompasses multiple, sometimes competing, institutional logics where long-term demands on sustainability often are at odds with short-term financial goals and politics. The aim of this paper is to increase the understanding of how actors navigate within such complexity in order to translate governmental energy efficiency directives into local practices. Data was collected through an ongoing case study of a facility management organization in Sweden. Focus is on a single institutional actor, a project manager and his (institutional) work of creating and implementing new energy directives. Findings show that translating energy-efficiency directives into practice is not a straight forward process and, together with other issues, requires considerations of the interplay between different logics. In order to manage this, the project manager was switching between strategies of 'zooming in' and 'zooming out' i.e. either focusing on single and narrow logics or integrating them at different stages of the process. By elucidating the more practice-based simplifications that also is adopted by the project manager, we instil the need for more nuanced conceptualizations of complex institutional landscapes, being a central concern for researchers and practitioners engaged in the sustainability challenge in the built environment sector.

Keywords: institutional logics, public facilities management, work practices

INTRODUCTION

In Sweden, a particularly large number of public buildings were built during the period 1965 to 1974 as part of a political vision. These buildings, including both public housing and public premises, now need to be renovated or even replaced as they face several problems including meeting today's energy efficiency demands, and other goals related to sustainability. Responsible for these buildings, and important players for the development of sustainable facilities management (FM), are public facilities management organizations (PFMOs). The inherent organizational complexity and the multifaceted decision-making structure place high demands on PFMOs (Hopland 2016) as they are confronted with requirements that represent targets and ambitions of political bodies (Hartmann *et al.,* 2008), as well as the juridical context of legislation, rules and bureaucracy (Kuipers *et al.,* 2014). Adding to the complexity; the practices and ethics of public FM cannot be viewed in isolation from the development of a business ditto (Galamba and Nielsen 2016). For instance;

[1] ingrid.svensson@chalmers.se

Svensson, I and Löwstedt, M (2019) Navigating the Logics of Changing Public Facilities Management *In:* Gorse, C and Neilson, C J (Eds) *Proceedings of the 35th Annual ARCOM Conference,* 2-4 September 2019, Leeds, UK, Association of Researchers in Construction Management, 730-739.

renovation decisions are exposed to long-term demands on energy efficiency, governmental and corporate sustainability directives, while being governed by short-term financial goals and politics at the same time (Higham *et al.,* 2015). These two overarching perspectives call for different responses in practice (Rey and Higgins 2009). Specifically, (public) building renovation takes place in a context of multiple, and sometimes competing (institutional) logics, such as economics, project practice, energy efficiency, and sustainability (Hill *et al.,* 2013; Gluch *et al.,* 2018). The current body of literature on public and sustainable FM mostly encompass issues such as; best practice, decision support tools, financial savings, technical engineering, health and safety issues, together with research on barriers/hinders for sustainable facilities management (Nielsen 2016; Campbell 2017). However, the above-mentioned conditions imply that change in work practices is both needed and happening at different levels of the organizational nexus of public FM (Gluch and Svensson 2018), and that theories and research methods subsequently need to be geared towards both the level of practice as well as the wider (institutional) context, in order to capture the essence of the transformations that PFMOs currently are subjected to (Galamba and Nielsen 2016). Research on sustainable FM could and should encompass both technical issues as well as social ones (Bröchner *et al.,* 2019) and researchers are suggested to view and understand (new) practices within the context of their use (Hill *et al.,* 2013). According to Bröchner *et al.,* (2019), environmental, social and economic sustainability will be the basis for joint solutions for tomorrow's sustainable FM. This implies that the actors need to find ways that enable collaboration and integration of the multitude of logics prevalent in PFMO´s, rather than ending up with some logics overrunning others (Thoresson 2015). Drawing on a practice-based institutionalism we explore the actions and strategies (i.e. institutional work (IW)) of a project manager working for a PFMO in Sweden with the ongoing implementation of governmental energy directives, while simultaneously managing a large building stock in need of renovation. The paper aims to increase the understanding of how actors (can) navigate within (such) complex institutional landscapes, in order to translate governmental energy efficiency directives into local practices.

Theories of IW (Lawrence and Suddaby 2006) and institutional logics (IL) (Friedland and Alford 1991) are suitable when trying to understand how local practices are linked to a wider institutional context, such as the organizational field of PFMOs. Traditionally, institutional theory has foregrounded "embeddedness" over "situatedness" (Smets *et al.,* 2017); in fact, contemporary practice perspectives are in part a counter-point to previous institutionalist positions that held the notion that the social world is external to actors. However, with an interest in IW and ILs, a shift can be seen within institutional theory in which practices has become a focal point of interest. Our focus on a practice perspective highlights how one institutional worker creates new practices in an institutional context characterized by multiple embedded logics, both pre-existing and new ones.

In any given field, there are so called ILs, or sets of "material practices and symbolic constructions" (Friedland and Alford 1991) that shape meanings, give legitimacy, determine issues, problems and solutions, and have an impact on change (Thornton 2002). ILs shape and create the "rules of the game", they represent sets of expectations regarding social relations and behaviour (Goodrick and Reay 2011). As social actors rely on their understandings of a certain logic, so does their understanding of what behaviours or what materials that bring status and power in an

organization which is organized under that logic (Thornton and Ocasio 2013). The change in work practices that are needed in PFMOs can be seen as a change in what governs public FM; and consequently, a change in the logics underpinning PFMOs. When investigating (changing) ILs, researchers have been encouraged to adopt a practice-based perspective and to study the connection between logics and organizational practices (Smets *et al.,* 2017).

The importance of studying how multiple logics play out and are acted upon and continuously re-constructed in practice has been stressed; there has been a stream of work showing that many fields are guided by multiple logics over time (e.g. Lindberg, 2014; Dunn and Jones, 2010). Multiple logics can both compete and cooperate (facilitate one another) in practice (Goodrick and Reay 2011) and sometimes logics can be "used" strategically, and not necessarily enacted in some pure and distilled form (Venkataraman *et al.,* 2016). In this context, Ludvig *et al.,* (2013) have shown the importance of possessing communicative skills and discursive competencies when implementing energy efficiency directives (and introducing new logics) in public construction organizations. They highlight the need for change agents to frame and anchor politically directives in local practice in order for them to be executed.

This paper draws on data collected in a case study at the facility management office (FMO) in the city of Gothenburg (Sweden), between the beginning of 2016 and the end of 2017. The FMO build and manage various municipal premises, including, schools, preschools, housing for elderly and housing for people with special needs. For this paper, we have focused on how the FMO works with "hard" facilities management issues, such as; maintenance, renovation and reparations etc. The FMO is providing premises for public administration in 10 different City Areas (CA), each area operating according to a separate budget. The Facilities Secretariat (FS), with 7 officials, is responsible for the strategic planning of municipal premises for the CAs and coordinates the need for, and use of, premises in the city. Another influential body operating within the realms of the FMO and the FS is the Municipal Facilities Board (MFB). The MFB consists of laymen politicians, mandated to decide on the focus, goals, policies and directions that governs both PS and FMO's operations. Specifically, we seek to understand how the FMO worked, in practice, with a transformation towards a more strategic management of their portfolio of premises. They developed and tested this practice in a pilot-project (hereafter referred to as the 'strategy project') between March 2016 - September 2016. The pilot project team consisted of one project manager, (coordinator and from FMO, FM by training), one representative from FMO (a FM), one representative from PS (planning manager), one consultant and one representative from the City Area where the pilot should take place (architect). The project manager was also responsible for moving the pilot project from its test-area to the whole city and organization. In the early stages a sustainability manager was also part of the team. Later on, a financial manager became part of the pilot project team. The strategy project was initially only directed towards energy efficient renovation of pre-schools but emerged to entail all sorts of public premises throughout the city and a multitude of measures. Little by little the project transformed from its pilot version to become an organizational practice, referred to as "strategic facilities planning".

DATA COLLECTION AND ANALYSIS

The data collection spans a period of 1,5 years, divided in two main phases conducted by the first author of this paper. In the first phase, the unfolding of the strategy project

was closely studied, from the initial idea phase, and throughout its prolonged development and implementation. The data consists of 15 in-depth semi-structured one hour- interviews with 12 different persons, field observations of meetings and presentations, and analysis of documents and PowerPoint presentations concerning the strategy project, those used both externally (mainly to political laymen) and internally, within the FMO. A year after the pilot project officially was completed (and the new more strategic facility planning practices allegedly were in place) the FMO was revisited for a second phase of data collection. All interviewees from the first phase were inquired again to participate in follow-up interviews. Eight out of the original twelve agreed, while four were unable (rather than unwilling) due to several reasons, such as, sick leave, changes of workplaces etc. Two additional employees at the FMO were interviewed instead. In addition; seven interviews with the strategy project manager were conducted from February 2016 to October 2017. A short questionnaire was e-mailed to all the Facility Managers (FMs) at the FMO. We were interested to see how "strategic facilities planning" was perceived and understood amongst the FMs, since their work practices were going to be directly affected by this new way of working, and they would be involved in the implementation. 8 out of 13 responded.

Our data analysis was aimed at exploring the perspective of one particular institutional worker. More specifically, we focus down at the project manager´s perspective, as he was progressing the strategy project by means of navigating multiple logics in a complex institutional milieu (Smets *et al.,* 2017). Through the analysis we followed Reay and Jones (2016) and considered 'logic' to be the pattern and interplay among symbols, beliefs, norms, and practices that guide people in an institutional setting, thus; socially constructed values and beliefs that guide behaviours. Such logic can be revealed by language, practices, and manifested in symbols and materials (ibid). Drawing on multiple methods our case study offered fruitful grounds to understand, challenge, nuance, and contextualize the storylines of the project manager by combining scrutiny of language (interviews), practices (observations), and symbols and materials (written documentation). It is of importance to note here that there exist no "ILs" in the world per se, it is rather a conceptualization that is deployed to instil some order in the world of organizations and their environments (Zilber 2013). The findings section is therefore to be understood as our own conceptualization of the project manager´s work to translate energy efficiency targets into organizational practices; by means of successfully navigating through the multitude of different logics that constitute the institutional landscapes of FMOs.

FINDINGS

We identified two general themes of strategies for institutional work that were used by the project manager in developing and implementing the strategy project in the PFMO; 'zooming in' and 'zooming out'. These themes refer to the two general approaches of, on the one hand set aside organizational complexities and zoom in on specific logics, levels, or tasks at certain points in time, and on the other hand, to be able to zoom out; looking at the "nexus" from a far and integrating multiple logics. In reality, these strategies overlapped at times, but we believe that the two simplified themes indeed reveal something central about being a manager in the context of PFMOs. The findings are not presented as a linear process, but rather as snapshots of the actual process.

Zooming in

Keeping cool (and carry on): This category refers to the ability of the project manager to focus only on what was right in front of him and his team on the project agenda, thus carrying on as planned and temporally disregarding the tensions deriving from the project´s broader organizational and institutional surroundings. For instance: the political logic unfolding in parallel with the project. The political laymen and politicians who carried the decision mandate for some mandatory demands imposed on the PFMO studied, indeed took their time making decisions. This was in part for administrative reasons and also because their decisions, in turn, was 'sequenced' together with broader decision-making concerning the re-organization of the whole city administration. The uncertainty related to this could indeed have instilled a lot of ambiguity for committing to progress in the strategy project. However, the project manager did not wait for this group to make decisions, but kept his own project running even though the politicians had not yet approved of the ideas. The project manager reflects on this in the following way: “If this new way of working is to be implemented formally and all the way, in the entire city, with all kinds of premises, the politicians need to agree upon the ideas. However, in the current stage, we just continue working as we do. Even if the politicians have not said yes yet…we just continue.” When asked by a facility manager if it is really any use to start working according to the new way, while all these other discussions concerning the comprehensive re-organization are going on, another project member echoes the view of the project manager: “We keep on doing our thing”. "You just hold on as much as you can". Thus, outwards, at project meetings and presentations, the rhetoric of the project manager (and the project team) was that the project was already rolling (although formally things were not set).

Personify: This category refers to zooming in all the way down to the individual level, where it foremost was the interactions with individual persons that regulated the day-to-day decision-making and practices. Various kinds of ILs were thus internalized in certain persons. The responsiveness to individual and personal encounters seemed particularly important in the early phases of the project. Setting up the project entailed forming a group of people from different organizations, carrying with them different logics, perspectives, and stakes into the project team. To "personify" thus refers to the observation that these people seemed to translate the understanding of complex ILs to more intuitive and emotional associations linked to the specific person that represented it. One example of this was how important it was to choose the "right" person to represent the FMs. The city area chosen as the pilot area was chosen because the particular manager responsible there was deemed "a little bit better " than the rest and would also be willing to easily accept and develop the new ideas. He was seen as competent and someone people from different organizations unanimously would accept to work with. Previous experiences from the FMO and the PS had shown the importance of developing personal relationships, so that people have confidence in each other and not discard ideas based on organizational belonging. This was acknowledged by the project manager who put together a team of people that he thought could work together, despite previous quarrels between certain organizations. The representative from the PS started his first meeting with the pilot project group by saying: "Well, you all know me, I am from (name of his organization). Am I famous…or in-famous…heh heh…I do not say anything more? (He here referred back to some previous cooperation problems between the organizations.) This statement was followed by laughter from all participants. The

small talks following the laughter testified that the group unanimously respected and accepted that particular person himself, so that any grudges against the organization he represented could now be put aside. To personify refers to how individual interaction directly regulate outcomes and directions for the navigation of the complex institutional context, where any overriding logic temporality is internalized in various persons.

Acknowledging the importance of professional's logics: Although being a project open for interpretation and possible to identify with for a majority of people within the organizational nexus (See zooming in: integrating logics), the project manager needed to make some decisions regarding who to please the most, especially in the development phase of the project, i.e. whose professional logic(s) to relate to among the workers who would execute the new ideas in practice. In the organization, there had been both former real estate agents working as FMs alongside more technical oriented FMs. For the former real estate agents, their work had mostly focused on the client relationships rather than the facilities in themselves. With strategic facilities planning, more technical demands were put on the FMs, thus the new ideas were more suitable for FMs with an educational background other than real estate together with the engineers working as project managers for renovation projects. In order to pursue his means, the project manager was able to identify with the (technical) FMs and project managers and navigate forward by focusing specifically on the needs (zooming in) of these specific professional groups. The existing logic, both within the FMO and PFMOs in Sweden in general, that the engineers and FMs had been "forced" to relate to, was a project practice / "patch and mend" logic. Measures had been conducted ad-hoc; "we could only "put out fires" and handle the most acute things", says one FM. "There was no long-term planning at all" adds the project manager. This meant that FMs and engineers had not been able to do their job according to their professional training, which according to them involved long-term thinking and proper planning. When presenting the new ideas connected to the strategy project, the project manager emphasized the long-termless of the project, its strategies and by that, although not explicitly, telling the technical FMs and engineers that they would now be able to work according to their professional training and hence their professional logics. By acknowledging a specific type of logic that can be said to have been "in-active" in practice (i.e. the professional logic of the technical facilities managers and engineers) together with being zoomed in and attentive to the "frustration" that these people felt, the project manager managed to get a crucial set of people to agree on the ideas and the way forward. The (technical) FMs and engineers expressed that it would be "a relief" to work according to strategic facilities planning; this new way was really "the obvious and natural" way to perform as a FM / engineer and was in contrast to the "ad-hocness" of the way things had been done before. They were all very enthusiastic about the new way of working and thus important players to have "onboard".

Zooming out

Emphasizing collectivity: Once the members of the pilot project team had established an initial consensus and comfort based on personal relationship, they seemed gradually to consider instead the collective and aggregated efforts. Thus, while 'personify' is about letting immediate behaviour and decision-making be guided by encounters with individual persons, 'emphasizing collectivity' refers instead to the modus of being guided by the collective. During the meetings at the later stages of the project instead of focusing on organizational issues that might prevent the group from

working together, emphasis was put on their mutual core values. Issues on how to share important information, that was not possible today, was solved by referring to a joint future wanted IT-system - a system that they hoped would be invented in the future. They removed the obstacles for the moment and were able to work together as a unified group that were to come up against their common counterpart: the politicians. Not as individuals nor representatives from different organizations but as a unified group with a shared vision. Being a unified group was also emphasized when the strategy project was presented for employees at the CAs and FMs at the FMO and he project manager talked in terms of "we" together have made this or that within the project, not mentioning who "we" are. Thus, instead of dwelling on their differences he de-personalized and unified the group, focusing on their common visons and ideas, thus was able to zoom out.

Integrating logics: Being able to zoom out, the project manager (together with colleagues) rather quickly realized that energy efficiency measures alone would not be enough to gain legitimacy for the strategy project. The project manager articulated that the politicians that gave the directives would not accept a proposal that only accounted for energy efficiency measures, since for the politician's financial means were important i.e. a financial logic was governing their actions. What was more; the strategy project still needed to comply with the energy efficiency means of the organization as well as adhere to the professional logics of the FMs and engineers at the operational level as discussed above. Thus, with the strategy project, the project manager needed to be able to synthesis and integrate different logics and perspectives.

The concrete practice of planning for evacuation into existing buildings, a result of the strategy project, can be seen as a product of negotiations around the tensions posed by the overlay of multiple logics in the FMO and the ability of the project manager to integrate these. A necessary condition in order to be able to evacuate into existing buildings was to find the empty spaces, enabled by what most FMs stated as the purpose with "strategic facilities planning": "The FMO now has a more holistic "picture" regarding their building stock". By evacuating into existing buildings FMO did not need to rent as many energy consuming pavilions and by that "pleasing" the ones who favoured the energy aspect of the project: such as the director of the FMO. For him the strategy project was mainly linked to a general "environmentally friendly" agenda and he says: "the proposed evacuation will demand for less usage of temporary buildings (pavilions), which are extremely bad for the environment." Notably, for the project manager himself, who was working closely with the people on the project/ operational level: "the strategy project … is not so much related to these environmental goals and to those things." This could be seen as a contradiction since we above stated that he made the project open to fit different means. However, the strategy refers to the ability to be able to zoom out from individual needs and create something that many could adapt to. This does not necessarily mean that the project manager himself was equally committed to all aspects. Not renting pavilions also meant saving money and for the project manager, this aspect was of most importance; he says that "working with strategic facilities planning has been great since it enabled me with the possibility of helping the city save money". The financial aspects were also endorsed by one of the development managers that worked for all FMO: "The economical sustainability is absolutely the overall aim of the work with strategic FM", and for the politicians as mentioned above. Thus, "Strategic facilities planning" was open enough to fit the needs and likings of different people throughout the organizational nexus.

Knowing the nexus - "where" are the different logics to be found? The project manager could see that at different levels of the organizational nexus of the FMO, people were guided by different logics, and hence needed different arguments and arrangements in order to "buy" into the ideas and practices that came along with "strategic facilities planning". To show how this was done in practice we have two examples of groups that needed to be convinced: the politicians and political laymen (i.e. located at the field level) and the professionals at the operational/project level, and a brief summary of how they were argued to. The first time 'strategic facilities planning' was presented to public officers (financial director of the city) the financial director of FMO was in charge of the presentation and the project manager had a background role. The financial dimensions of the strategy project were further endorsed by this opening line form the financial director: "In the end, it's all pennies and dimes, that is not actually what we should be talking about, or working with, but that is how it goes." Thus, in meetings with the politicians. i.e. close to / at the field level, the financial aspects of the strategy project were endorsed. However, in order to promote 'strategic facilities planning' at the operational level, the project manager did the presentations and the strategic dimensions were endorsed to a larger extent. These examples show that the project manager had "sense" of the nexus and the logics' placements within it, although he did not talk in such terms.

DISCUSSION AND CONCLUDING REMARKS

We have investigated how one actor navigate within the complex institutional setting of a Swedish PFMO, in order to translate governmental energy targets into (new) local practices. Our findings indeed elucidate the multiple ILs at play in the transformation towards more sustainable FM (Dunn and Jones 2010; Hill *et al.,* 2013) a transformation that we labelled an 'institutional change'. If adopting the common conceptualization of change and ILs, in which institutional change often is portrayed as a replacement of one dominant (institutional) logic for another (Thornton and Ocasio, 2013), several aspects of the process studied would probably either have been missed or misunderstood. In particular, the different strategies needed by the project manager, at different parts of the organizational nexus (Gluch and Svensson 2018) and in different times of the process, would risk lacking much central nuance, if it wasn't for the first-person view adopted in this paper. We found that several logics were at play in the organization, and that at times the project manager notified and made use of a multitude of these strategically (Venkataraman *et al.,* 2016). However, at other times his gaze was focused merely on pragmatic versions of single logics, one at a time, in order to accompany day-to-day expedient actions. We also propose that the project manager "activated" a logic that had been "in-activated" within the organization: the professional logics of the technical FMs and engineers. For future research, this raises the question of what constitutes as an active or in-active logic and how do they impact organizational processes? (What) is there a difference in impact of inactive vs active logics on organizational processes?

Whereas researchers nowadays often conceptualize institutional landscapes as being "complex" and consistent of "a multitude of logics" (e.g. Zilber 2013), the project manager himself did not talk about his day-to-day context in terms of neither "logics", nor was he overwhelmed by their "multitude" or "complexity". As our findings elicit, rather than seeing the multiple logics milieu as a problem, the project manager in our study seemed to acknowledge his scene, accept it and actively navigating it with curiosity. Our findings lend weight to the fact that successful practitioners need to both be aware of their institutional context but also refrain from getting paralyzed by

the vast institutional complexity in their daily work. While this dynamic approach served the manager from FMO well, we found it interesting to note that he himself did not seem to explicitly reflect upon these types of strategies. He was purposively creating new practices, maintaining and destroying others, but seemed less reflective in terms of the way his actions were adjusted to reach his purpose (i.e. his strategy). This would be interesting to elaborate on further, in future research. The questions could be something in line with: How much, or, what part of, the managers practices (IW) are explicit and how much /what is implicit?

We have conceptualized the project manager´s ongoing IW as two thematic strategies of zooming in and zooming out respectively. It seemed as if the strategies sorted under the 'zooming in' category were used more in early phases of the project, whereas 'zooming out' were used to a larger extend in the later stages, as the project slowly but steadily became more embedded in its institutional surroundings. By focusing on these two strategies for IW, this paper offers a more nuanced understanding of the seemingly growing complexity of the institutional landscapes underlying sustainable public FM. In practice, single actors do not need to, and cannot, take into account all this complexity at once, but is handling the day-to-day work partly by effectively ignoring and/or prioritizing. These skills are needed, as future (sustainable) FM needs to find ways to integrate both environmental, social and economic sustainability (Bröchner 2019). We propose that the way we have conceptualized PFMOs; as a field characterized by multiple types of actors and stakeholders with multiple logics of varying strengths, depending on the location within the organizational nexus, could possibly be generalized across the construction sector; future studies could look into how a variety of measures are implemented and translated into practice.

REFERENCES

Bröchner, J, Haugen, T and Lindkvist, C (2019) Shaping tomorrow's facilities management, *Facilities*, 37(**7/8**), 366-380.

Campbell, L Z (2017) An exploration of how research can aid the development of facilities management, *Facilities*, 35(**5/6**), 356-366.

Dunn, M B and Jones, C (2010) Institutional logics and institutional pluralism: The contestation of care and science logics in medical education 1967-2005, *Administrative Science Quarterly*, 55(**1**), 114-149.

Friedland, R and Alford, R (1991) Bringing society back. *In:* W W Powell and P J DiMaggio (Eds.) *Symbols, Practices and Institutional Contradictions the New Institutionalism in Organizational Analysis*, London: University of Chicago Press, 232-263.

Galamba, K R and Nielsen, S B (2016) Towards sustainable public FM: Collective building of capabilities, *Facilities*, 34(**3/4**), 177-195.

Gluch, P, Gustafsson, M, Thuvander, L and Baumann, H (2014) Charting corporate greening: Environmental management trends in Sweden, *Building Research and Information*, 42(**3**), 318-329.

Gluch, P and Svensson, I (2018) On the nexus of changing public facilities management practices: Purposive and co-creative actions across multiple levels, *Construction Management and Economics*, 36(**5**), 259-275.

Goodrick, E and Reay, T (2011) Constellations of institutional logics - changes in the professional work of pharmacists, Work and Occupations, 3(**38**), 372-416.

Hampel, C E, Lawrence, Thomas B, Tracey, P, Greenwood, R and Oliver, C (2015) Institutional work: Taking stock and making it matter, *In: SAGE Handbook of Organizational Institutionalism 2nd Edition*. London: Sage Publications.

Hartmann, A, Reymen, I and Oosterom, G van (2008) Factors constituting the innovation adoption environment of public clients, *Building Research and Information*, 36(**5**), 436-449.

Higham, A, Fortune, C and James, H (2015) Life cycle costing: Evaluating its use in UK practice, *Structural Survey*, 33(**1**), 73-87.

Hill, S, Lorenz, D, Dent, P and Lützkendorf, T (2013) Professionalism and ethics in a changing economy, *Building Research and Information*, 41(**1**), 8-27.

Hopland, A O (2016) Long-run relationship between investment and maintenance in local governments, *Facilities*, 34(**11/12**), 703-722.

Kuipers, B S, Higgs, M, Kickert, W, Tummers, L, Grandia, L and Van Der Voet, J (2014) The management of change in public organizations: A literature review, *Public Administration*, 92(**1**).

Lindberg, K (2014) Performing multiple logics in practice, *Scandinavian Journal of Management*, 30(**4**), 485-497.

Lawrence, T B and Suddaby, R (2006) Institutions and Institutional work. *In*: S R Clegg, C Hardy, T B Lawrence and W R Nord (Eds.) *Sage Handbook of Organizations Studies 2nd Edition*. London: Sage, 215-254.

Ludvig, K, Stenberg, A and Gluch, P (2013) The value of communicative skills for developing an energy strategy, *Building Research and Information*, 41(**6**), 611-621.

Nielsen, S B, Sarasoja, A-L and Galamba, K R (2016) Sustainability in facilities management: An overview of current research, *Facilities*, 34(**9/10**), 535-563.

Powell, W W and Colyvas, J A (2013) Microfoundations of institutional theory. *In*: R Greenwood, C Oliver, K Sahlin and R Suddaby (Eds.) *The SAGE Handbook of Organisational Institutionalism*. London: Sage.

Reay, T and Jones, C (2016) Qualitatively capturing institutional logics, *Strategic Organization*, 14(**4**), 441-454.

Smets, M, Aristidou, A and Whittington, R (2017) Towards a practice-driven institutionalism, *In*: R Greenwood, C Oliver, T B Lawrence and R Meyer (Eds.) *The Sage Handbook of Organizational Institutionalism*. London: Sage.

Thoresson, J (2015) Omställning-tillväxt-Effektivisering Energifrågor vid renovering av flerbostadshus, Doctoral Thesis, Linköping University, Linköping.

Thornton, P H and Ocaiso, W (2013) Institutional logics. *In*: R Greenwood, C Oliver, K Sahlin and R Suddaby (Eds.), *The SAGE Handbook of Organizational Institutionalism*. London: Sage.

Venkataraman, H, Vermeulen, P, Raaijmakers, A and Mair, J (2016) market meets community: Institutional logics as strategic resources for development work, *Organization Studies*, 37(**5**), 709-733.

Zilber, T B (2013) Institutional logics and institutional work: should they be agreed? *Research in the Sociology of Organizations*, 39(**A**), 77-96.

BEYOND NATIONAL BUILDING REGULATIONS: EXPLORING PUBLIC-PRIVATE NEGOTIATIONS OVER SUSTAINABILITY REQUIREMENTS

Melissa Candel[1], Tina Karrbom Gustavsson[2] and Per Erik Eriksson[3]

[1&2] *Department of Real Estate and Construction Management, School of Architecture and the Built Environment, KTH Royal Institute of Technology, Teknikringen 10B, SE-100 44 Stockholm, Sweden*

[3] *Department of Business Administration, Technology and Social Sciences, Department of Civil, Environmental and Natural Resources Engineering, Luleå University of Technology, 97187 Luleå, Sweden*

Municipalities in Sweden govern construction projects on municipal land through requirements that sometimes go beyond national building regulations in order to advance sustainable building practices. The purpose of this paper is to explore the process of negotiating such project specific requirements for construction projects built by private housing developers on municipal land. The paper builds on a case study of an innovative urban development programme in Stockholm where interviews with private housing developers and municipal representatives and observations of meetings, seminars and forums were conducted. Emerging negotiations between the municipality and private housing developers over project specific requirements set by the municipality were explored and analysed using the concepts of product and process innovation. Findings reveal that housing developers try to remove or change those requirements that are considered to increase costs, increase risks and decrease the value of their final product. This paper illustrates how project requirements for construction projects on municipal land are dependent upon early phase negotiations between the municipality and housing developer.

Keywords: municipality, innovation, sustainability, negotiations, procurement

INTRODUCTION

Construction clients are considered to play a key role in initiating innovations in construction because they set requirements for construction projects through procurement (Nam and Tatum, 1997; Hartmann *et al.,* 2008; Harty 2008; Haugbölle *et al.,* 2015). However, local governance research has revealed that municipalities use land allocation agreements to govern construction projects on municipal land in order to advance sustainable development (Bulkeley and Kern, 2006; Smedby, 2016; Smeby and Quitzau, 2016). Through land allocation, municipalities can place requirements on construction projects that go beyond national building regulations (Caesar, 2016; Smedby and Quitzau, 2016; Smedby, 2016). Hence, in construction projects developed on municipal land, construction clients (here called housing developers) do

[1] candel@kth.se

Candel, M, Gustavsson, T K and Eriksson, P E (2019) Beyond National Building Regulations: Exploring Public-Private Negotiations Over Sustainability Requirements *In:* Gorse, C and Neilson, C J (Eds) *Proceedings of the 35th Annual ARCOM Conference,* 2-4 September 2019, Leeds, UK, Association of Researchers in Construction Management, 740-749.

not alone decide on the requirements for their projects (Caesar, 2016; Smedby and Quitzau, 2016; Smedby, 2016).

During the early planning phases of these construction projects, after land has been allocated to a housing developer and before a definite development right is established, the municipality's requirements are subject to modifications (Caesar, 2016). This means that housing developers have an opportunity to negotiate and influence modifications of the municipality's requirements, making the governance of these projects, and the initiation of innovation in construction, a dynamic process. The purpose here is to explore the process of negotiating project specific requirements for construction projects built by private housing developers on municipal land.

A case study of an urban development programme was carried out. This programme includes several construction projects with project specific requirements set by the municipality intended to necessitate sustainable innovation. Through interviews and observations, the negotiations that arose as a result of project specific requirements set by the municipality were studied. To understand why these specific requirements proved to be especially problematic for the housing developers, they were analysed using the concepts of product and process innovations. The findings contribute to advancing construction management literature by showing how project specific requirements for construction projects on municipal land are established before the procurement process takes place. Contributions are also made to the understanding of the early project phases in innovative urban development programmes and the importance of these phases. The findings have practical implications for housing developers since project requirements are integral to their ability to govern construction projects. The findings also have implications for municipalities since they illustrate what happens when public actors challenge the private sector with sustainability requirements that go beyond the national building regulations.

Construction procurement can be seen as a governance mechanism that enables clients to incorporate sustainability requirements in their construction projects (Varnäs *et al.,* 2009; Petersen and Kadefors, 2016). Previous research on procurement often takes the perspective of the construction client, focusing on procurement strategies and their effects (e.g. Eriksson *et al.,* 2017). However, Ivory (2005) argues that clients are risk averse and act as barriers because the high risks associated with construction innovations make them unprofitable. Further, Harty (2008) argues that adoption and implementation of innovation in construction projects involves a complex process of negotiations with project stakeholders. Hence, the general view of the client as having the key role in driving innovation in construction warrants further investigation. This view is challenged by construction projects developed on municipal land where a municipality places their own requirements on sustainability (Caesar, 2016; Smedby and Quitzau, 2016; Smedby, 2016). The role that housing developers play in driving innovation in these construction projects will instead depend on the negotiations over project specific requirements set by the municipality. In order to understand the process of negotiating these project specific requirements, it is first necessary to explore the reasons why the housing developers decide to challenge them in the first place. These considerations raised the first research question:

RQ1: What type of project specific requirements are contended by private housing developers and why?

In order to gain an understanding of how these requirements stand out, the nature of the innovation that the housing developers anticipated would be involved in meeting

them is investigated. This enabled a better understanding of the differences between these project specific requirements and what make them especially problematic and challenging. Here we distinguish between product and process innovations, which is a common classification or categorization found in the innovation literature (Hullova, *et al.,* 2016). Damanpour and Gopalakrishnan (2001; 47-48) define product innovations as "new products or services introduced to meet an external user or market need" and process innovations as "new elements introduced into an organization's production or service operations…to produce a product or render a service". The various requirements from the municipality would trigger innovation efforts that can be categorized as product or process innovations, or both. The arguments used to discuss and negotiate these requirements are then investigated and the way these negotiations unfold is explored in order to answer the second research question:

RQ2: How are project specific requirements negotiated between private housing developers and the municipality?

METHOD

The findings build on an on-going case study of Stockholm Royal Seaport (SRS), an urban development programme with high requirements on sustainability that have been set by the municipality. The specific stage that was studied (Stage X) consisted of twelve private sector housing developers. The case study enabled us to develop in-depth context-dependent knowledge of the process of negotiating requirements (Flyvbjerg, 2006). This process was studied during the phase following the allocation of land to specific housing developers. Two sets of requirements were pointed out as special for Stage X by the municipality. One concerned low-flushing toilets that were to be connected to a self-sorting sewer system, and the other concerned a shared garage. These requirements were also pointed out by the housing developers' project managers as the most problematic and challenging requirements set by the municipality. In order to provide a more comprehensive picture of how these negotiations unfolded, both the housing developers' and the municipality's perspectives were explored.

The empirical material consists of 16 semi-structured interviews, non-participant observations and document analysis. Interviews were conducted with ten project managers from the housing developers in Stage X (HD1-10). These developers most notably varied in size and experience. Two housing developers had little to no experience building in Stockholm, two had experience building in Stockholm, and six had experience from previous stages in SRS. To gain the municipality's perspective and show the dynamic nature of these negotiations, interviews with three programme managers from the City Planning office (M1-3) were also conducted. A sustainability strategist (ST), a consultant (C) and a contract lawyer (CL) from the municipality were also interviewed because they were involved in this process of establishing requirements. All interviews were between one and two hours in duration and were carried out between March 2018 and March 2019. The material also consists of non-participant observations from meetings, competence seminars and forums, which were organized by the municipality for the housing developers.

The material from the interviews and observations was categorized into groups of major ongoing discussions over requirements using NVivo, which were then analysed using the concepts of product and process innovations. To gain more general knowledge about the urban development programme and its context, the sustainability programme, the action plan in the land allocation agreement containing most of the

sustainability requirements, and the municipality's policy for land allocations were also studied.

SRS is a large, long and complex urban development programme in Sweden initiated by Stockholm municipality. It is located in an attractive and sought-after area of the city where the municipality has chosen to use their land as a testbed for innovative sustainable solutions. The central location also gives the programme publicity that enables the municipality to use it as a way of promoting their vision of being a sustainable city. The publicity and sustainable profile also provide the housing developers with good prospects for marketing themselves. Both the municipality and the housing developers therefore recognize this publicity as one of the main incentives for the housing developers to partake in the urban development programme.

In this programme, there are two important change agents. The municipality is the owner of the programme and sets high requirements on sustainability for the housing developers' construction projects that entail various forms of innovation. The housing developers have thereby taken on a more passive role as change agents in this case. The municipality's objective with the SRS programme is to, among other things, develop knowledge of sustainable solutions and construction practices (Stockholms Stad, 2017). SRS can therefore be considered an innovative urban development programme. One of the programme managers (M1) explained that: "Specifically for [Stage X] we are testing many different things. As part of this we have the mobility index and the self-sorting sewer system". These are the two sustainability requirements set by the municipality that sparked the negotiations explored in this paper. These requirements were considered the most problematic and challenging for the housing developers during the time of the study.

The study took place after the housing developers had been allocated land (Figure 1). During this phase, the municipality and housing developers work together in an inter-dependency-based relationship to produce a definite development right (Caesar, 2016). This process precedes the housing developers' procurement process and the municipality's establishment of a detailed plan for the neighbourhood. As the municipality developed a detailed plan, their understanding of the building conditions sometimes changed, resulting in modifications to their requirements. As the housing developers conducted pre-studies and developed their design and production solutions, they also became aware that certain requirements would be more challenging and expensive than initially expected and therefore tried to persuade the municipality to either remove or change them.

FINDINGS

Vacuum toilets (water and energy) - Implementing new technologies

One of the requirements that the housing developers negotiated concerned low-flushing toilets. The initial requirement from the municipality stated that "building should be prepared for sorting sewage fractions. Installed toilets should be extremely low-flushing (maximum one litre per flush) and connected to a separate pipe" and was under the heading "requirements that will be clarified later" (Stockholm Stad, 2015). Although, the technology required for the vacuum toilets is available on the market, it is new to the housing developers. Challenges would therefore involve the procurement of suppliers, fitting additional costs into the budget and managing risks involved in adopting a new technology. This requirement would, in other words, mostly require process innovations from the housing developers. One project

manager (HD4) explained that "there are very many questions so the costs to implement this are very high.

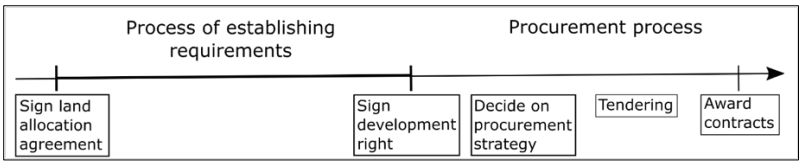


Figure 1: The process of establishing requirements from land allocation to procurement.

Labour costs and alternative costs because this drain chute needs to be included". From the housing developers' perspective, the risks associated with this requirement are to a large extent related to implementing a new system on a large scale, because "this has not been done on such a big scale before" (HD4). A common argument used to oppose this requirement regards maintenance. The housing developers argue that the new system would place unreasonable responsibilities on the housing corporations. For example, one project manager (HD5) pointed out: "What happens if they get clogged? It is the housing corporation that will manage these apartments and there are no housing corporations that have knowledge about it".

The vacuum toilets and sewer system became a major concern after the municipality presented their solution during a competence seminar. One project manager (HD6) said: "It turns out that they basically do not know what they will do with the waste... We have frustrated architects as well that we cannot give a time plan to. They cannot plan, we cannot plan". To make their expectations clear, the municipality also decided to specify what they wanted in an updated version of the land allocation agreement. The housing developers' project managers however perceive this as a change in requirements because "it said that you 'can' use them, and it said 'should', and now it says that we are 'supposed to'. That is a really big difference. From the municipality's perspective it is just a way to clarify, but from the housing developers' perspective this means additional costs" (HD10).

Throughout the time of the study it remained uncertain whether or not the municipality would actually build another system to support the additional drain chutes that they require the housing developers to build. This became a major concern for the housing developers. As one of the project managers (HD5) explained: "They [the municipality] say 'you should build this system in this way but then we also want you to prepare for a tank because in the future we might decide that we also want to do a collected system or a closed system'… That means that it is not enough with only normal drain chutes, but we need additional drain chutes for these toilets". The municipality decided that the requirement would remain but are unable to say whether they will be able to build the treatment plant. One of the programme managers (M1) expressed some frustration over this saying that "it is difficult with this treatment plant. We cannot get more information about them, so we are stuck… It is a little bit difficult to stand behind something when we have not really decided what we will do".

Most of the critique from the housing developers concerns increased costs and value for money, which they argue is especially problematic due to the falling housing market. For example, one project manager (HD5) said: "What you have reduced is that one flush takes one litre of water instead of four litres of water and then we have a cost of quite a few million. And it is then you have to think, is this really what we should focus our efforts on?" The municipality however tried to rationalise the

benefits by arguing that "if you have sorting sewer systems you can recycle warm water and save a lot of extra energy in the buildings" (M2), which they thought might help them meet the high energy requirements. This point was continuously stressed by municipal representatives during a competence seminar that they had organised. The response from many of the housing developers was however that the cost for recycling this warm water would outweigh the benefits gained from saving energy.

Many of the housing developers also argue that the municipality has not considered the negative impact that these toilets will have on the indoor environment for the people living in the apartments. One project manager (HD10) asked: "Do customers that buy something that is so extremely expensive… want to have a toilet that sounds like an airplane toilet"? Another argument that the housing developers use is that more important concerns receive less attention due to this requirement and that "perhaps they [the municipality] should focus on certain questions. The noise is of course a deciding factor. If that is not resolved, we cannot build" (HD4). In response to all this criticism, the municipality held a meeting to discuss the various viewpoints regarding the requirement in order to decide what they should keep. One programme manager (M1) explained: "We had a meeting about these self-sorting sewer systems with different requirements. You might say a bit of a crisis meeting, because we have received a lot of comments. Based on these we had a discussion and took in the various comments to make a decision on what we should keep". The municipality also held a forum for the housing developers to meet suppliers of vacuum toilets.

Garage solution (transportation) - A collaboration and coordination challenge
The municipality placed a number of requirements on the garages as part of a mobility index and specified that each garage should have one entrance and be shared between several blocks. The garage solutions for Stage X can be seen as another instance where process innovation would be required from the housing developers. The challenge with this requirement is however not related to the implementation of any new technology, but rather finding ways to collaborate with many other housing developers and to coordinate with the municipality's construction of infrastructure in this tight inner-city urban development. One project manager (HD6) explained: "To build three blocks along with streets and to get the legal aspects with easements and shared facilities and ownership in the garage… All seven housing developers are not the same and do not think the same, so this creates conflict, not just between the housing developer and the municipality but between housing developers too". It is evident that many of the housing developers do not understand why the municipality chose this solution. For example, project manager HD10 said: "It is unnecessarily problematic… the problem or the circumstances could have been made easier from the beginning". In response to these concerns, the sustainability strategist (ST) and programme managers from the municipality point out that "this was included as a requirement already in the competition, that collaboration with both the municipality and with other housing developers […] it said that this was an important part" (M2).

Early in the process one housing developer took the initiative to investigate an alternative solution. Their project manager (HD2) said that they were hoping to use existing caves "instead of building a very expensive and very complex [garage], both in planning, production and property management phases, which we are forced into since this is a car free city district". Their argument was that this would make more sense "out of both a resource and economic perspective" and that by using "already existing resources, these caves, we could cover the whole city's parking needs" (HD2). The municipality however decided to reject this proposal. It turned out that

this was never an option since the requirement was connected to the mobility index and had been developed as a part of larger strategic decisions regarding the planning of traffic in the city.

The negotiations with the municipality however mainly revolve around trying to change the solution so that there will be one garage per block with separate entrances. One of the project managers (HD5) explained how "the big question has been whether it should be three separate garages with three separate entrances with one block that is responsible for its part and then we become a joint facility…. And the municipality wants it to be one entrance, so the connections lay under the ground". Another question that made the discussion about the garage solution go around in circles was the order in which the garage should be built. One project manager (HD4) explained that "there are culverts under the street, so we need to build in a certain order for the garage to work and in this case in another order for the noise requirements to work" so "the question was resolved but now it has come back again because in terms of practical implementation the solution does not hold either" (HD7). The municipality's response to the questions and criticism, for both the garage and vacuum toilets, typically involve resolving issues through dialogue and offering support in the form of competence seminars and forums. One programme manager (M2) said: "We get a lot of questions and then we need to handle that, create meetings and forums to meet their eventual critique and engage in dialogue. We also have additional competence seminars that are organised for the housing developers".

The major risks perceived by the housing developers are from the other housing developers since they are dependent on each other to build the garage. For this reason, much of the process innovation for the housing developers concerns the formulation of contracts. Project manager HD5 said: "How do we form contracts for this? Otherwise the biggest risks are related to what happens if somebody is unable to start or does not get financing. How does one handle that? Especially now when the municipality forces us together in this way". The requirements are therefore also negotiated between the housing developers. They decided to form their own forums to enable collaboration with the other housing developers they will be building the garage with and discuss possible solutions.

It is evident that there are many conflicting opinions. This is for example expressed by project manager HD2 when reflecting over discussions regarding access to the garage: "Someone maybe thinks it is ok to place one in the middle of the courtyard, but someone else think 'no they will pay so much they should have direct access'... A third thinks it is ok to walk 200m… Which solution should we have? And we need to agree around one product". The housing developers also have very different strategies regarding their collaboration. For example, one project manager (HD4) explained: "We have mostly been thinking about what things we can do together to make this easier and what would cost less if we did it together, but others in the group have thought more about 'what are the least possible things we can give away? What do we need to sign to be able to handle this on our own and not be dependent?'". While the larger housing developers with more experience seem to drive many of the discussions, the strategy for some of the smaller and less experienced housing developers is to not get involved because "there are so many with opinions so we do not need to voice ours because everyone else does that." (HD10).

The negotiations have led to some changes to the requirements regarding the garages. For example, one project manager (HD4) said: "The visitors parking was initially

supposed to go down in the garage and made this a lot more difficult. So it was a big advantage that they decided to remove that". The housing developers however decided that they would stop working on questions regarding the garage for the time being and "together we have said that now we do not want to do anything more. Stop spending money on something that we cannot use" (HD7).

DISCUSSION

In SRS, the power and authority typically associated with the construction clients' procurement is challenged by the municipality's requirements and authority. This goes against the general perception of the construction client and the role of their procurement found in previous literature (e.g. Nam and Tatum, 1997; Hartmann *et al.,* 2008; Varnäs *et al.,* 2009; Havenvid, *et al.,* 2016; Eriksson *et al.,* 2017). The housing developers are however challenging some of the municipality's requirements during the early planning phases after the land had been allocated and before a definite development right is produced. Their role rather resembles that of a gatekeeper as they attempt to control what aspects of the municipality's initiative will be implemented in their construction projects. The findings support Ivory's (2005) conclusion that construction clients will act as barriers to those innovations that they consider risky and unprofitable.

The housing developers are mainly opposed to those requirements that are perceived to result in increased costs, increased risk, and decreased value of their final product. The two requirements that they try to renegotiate are perceived to involve all these three drawbacks. This might mean that requirements that are thought to increase costs and risk while also increasing value, or vice versa, are not considered problematic enough for the housing developers to challenge. The negotiations mainly involve discussions about process innovations, which might be a result of the product innovations being something that is either outsourced or the responsibility of parties other than the housing developers' project managers. It is also important to remember that the requirements that they want to renegotiate are set by the municipality and go beyond the national building regulations. This is perhaps the main reason the housing developers consider these requirements as negotiable in the first place.

The housing developers' justification for challenging requirements are for the most part related to minimising risks and controlling the costs of their project. For this reason, the falling market has impacted their concerns over these requirements in different ways. For example, the main concern with the vacuum toilets is that the market will not pay for the new technology. For the garage, however, the concern is that the other housing developers will not be able to finance their projects. Since they are dependent on each other to build the garage this could negatively impact the other housing developers. The ways in which these negotiations are initiated and unfold is however more complex and dynamic. For example, the housing developers came together to challenge the municipality with one voice in discussions about the vacuum toilets. Here their intentions and wishes are well aligned with one another. For the garage, however, they all have very different opinions, which has led to a large variation in negotiation strategies. This variation could be equated to the difference in how well defined the final product is. The design of the final product for the garage had to be developed and negotiated to a larger extent.

The findings show that there are requirements for construction projects in innovative urban development programmes that are negotiated and established before the housing developers' actual procurement process begins. This means that the considerations

over sustainability observed in Swedish construction clients' procurement (e.g. Varnäs *et al.,* 2009) will in some cases have been established beforehand by a municipality. The process of establishing requirements from land allocation to the signing of a development right will influence the procurement strategy a construction client chooses to use. This has largely been overlooked in previous research on procurement strategies (e.g. Eriksson *et al.,* 2017). Findings also illustrate how project specific requirements are negotiated between housing developers and the municipality during the early phases of construction projects on municipal land. This means that the complex process of negotiations with project stakeholders over the adoption and implementation of innovation in these construction projects (Harty 2008) begin already during the early planning phases in discussions over requirements.

CONCLUSIONS

The process of negotiating project specific requirements for construction projects built by private housing developers on municipal land are explored. Findings illustrate that private housing developers attempt to negotiate requirements that they believe will increase costs, increase risks and decrease the value of their final product. As a means of understanding their concerns and arguments against these requirements, the concepts of product and process innovations are used to analyse the innovations that the housing developers expect will be necessary in order to meet them. It is demonstrated that requirements for construction projects in innovative urban development programmes are established in a process of negotiations that take place before the housing developers' procurement process. In these projects, the imperative role of the construction client and their procurement process is therefore downplayed in comparison to previous research (e.g. Hartmann *et al.,* 2008; Varnäs *et al.,* 2009; Havenvid, *et al.,* 2016; Eriksson *et al.,* 2017). The development of these requirements was however not followed through the housing developers' procurement process. Future research could therefore explore the development of requirements from these early phases through the procurement process as well.

Findings provide practical implications for both municipalities and private housing developers in innovative urban development programmes. The requirements set by the municipality allow them to promote the district as a sustainable and innovative part of the city, showcasing their efforts to improve sustainability. They should however also be aware that requirements that have a high risk of increasing costs, increasing risk and decreasing value for private housing developers will likely lead to negotiations. Municipalities would therefore benefit from considering how their requirements could affect the costs, risks and value of the construction projects in their programme to be prepared for the efforts needed to persuade private housing developers. This study also shows that private housing developers building on municipal land in innovative urban development programmes should be prepared to be faced with some requirements that might increase their costs, increase their risks and decrease the value of their final product. Negotiations can in some cases lead to requirements being modified or removed completely, but this is not a certainty.

REFERENCES

Bulkeley, H and Kern, K (2006) Local government and the governing of climate change in Germany and the UK, *Urban Studies*, 43(**12**), 2237-2259.

Caesar, C (2016) Municipal land allocations: integrating planning and selection of developers while transferring public land for housing in Sweden, *Journal of Housing and the Built Environment*, 31(**2**), 257-275.

Damanpour, F and Gopalakrishnan, S (2001) The dynamics of the adoption of product and process innovation in organizations, *Journal of Management Studies*, 38 (**1**), 45-65.

Eriksson, P E, Lingegård, S, Borg, L and Nyström, J (2017) Procurement of Railway Infrastructure Projects - A European Benchmarking Study, *Civil Engineering Study*, 3(**4**).

Flyvbjerg, B (2006) Five misunderstandings about case-study research, *Qualitative Inquiry*, 12(**2**), 219-245.

Hartmann, A, Reymen, I M M J and van Oosterom, G (2008) Factors constituting the innovation adoption environment of public clients, *Building Research and Innovation*, 36(**5**), 436-449.

Harty, C (2008) Implementing innovation in construction: contexts, relative boundedness and actor-network theory, *Construction Management and Economics*, 26(**10**), 1029-1041.

Haugbölle, K, Pihl, D and Gottlieb, S C (2015) Competitive dialogue: Driving innovation through procurement? *Procedia Economics and Finance*, 21, 555-562.

Hullova, D, Trott, P and Simms, C D (2016) Uncovering the reciprocal complementarity between product and process innovation, *Research Policy*, 45(**5**), 929-940.

Havenvid, M I, Hultén, K, Linné, Å and Sundquist, V (2016) Renewal in construction projects: tracing effects of client requirements, *Construction Management and Economics*, 34(**11**), 790-807.

Ivory, C (2005) The cult of customer responsiveness: Is design innovation the price of a client-focused construction industry? *Construction Management and Economics*, 23(**8**), 861-70.

Nam, C H and Tatum, C B (1997) Leaders and champions for construction innovation, *Construction Management and Economics*, 15(**3**), 259-70.

Petersen, D and Kadefors, A (2016) Social Procurement and employment requirements in construction, *In*: Chan, P W and Neilson, C J (Eds.) *Proceedings of the 32nd Annual ARCOM Conference*, 5-7 September 2016, Manchester, UK, Association of Researchers in Construction Management, 2, 997-1006.

Smedby, N (2016) Assessing local governance experiments for building energy efficiency - the case of Malmö, *Sweden* Environment and Planning C: Government and Policy, 34(**2**), 299-319.

Smedby, N and Quitzau, M B (2016) Municipal governance and sustainability: The role of local governments in promoting transitions, *Environmental Policy and Governance*, 26(**5**), 323-336.

Stockholms Stad (2015) *Hållbarhetskrav Vid Markanvisning Södra Värtan; Handlingsprogram Vid Planering, Projektering, Byggande Och Förvaltning Av Bostäder Och Verksamhetslokaler I Södra Värtan*. Stockholm: City of Stockholm.

Stockholms Stad (2017) *Sustainable Urban Development Programme; Stockholm Royal Seaport is Leading the Way to a Sustainable Future*. Stockholm: City of Stockholm.

Varnäs, A, Balfors, B and Faith-Ell, C (2009) Environmental consideration in procurement of construction contracts: Current practice, problems and opportunities in green procurement in the Swedish construction industry, J*ournal of Cleaner Productio*n, 17(**13**), 1214-1222.

FROM PROJECT TO POLICY: IMPLEMENTING A COLLABORATIVE PROCUREMENT STRATEGY IN A PUBLIC CLIENT ORGANIZATION

Lilly Rosander[1] and Anna Kadefors

Department of Real Estate and Construction Management, KTH Royal Institute of Technology, Teknikringen 10b, 100 44 Stockholm, Sweden

Following urbanization and higher sustainability goals, large and complex infrastructure construction projects are becoming more common. New collaborative contracting models are increasingly used to tackle this complexity and uncertainty. In a public context, collaborative contracting may be seen as an international trend in public policy, which is implemented in projects by public clients world-wide. Since a few years, the Swedish Transport Administration recommends that a two-stage Early Contractor Involvement should be used for very large and complex projects. This paper analyses the implementation of this model in two sub-projects in a large Swedish infrastructure project based on policy implementation literature. Altogether 24 interviews were performed in two rounds, capturing both early expectations and experiences gained after the contracts had been signed. Participants expressed positive attitudes to the new collaborative project practices. However, the implementation process was characterized by ambiguity and many issues about staffing, collaboration processes, target cost estimations, responsibilities and design output were left to the projects to resolve. The study shows how conflicting policies and high project-level autonomy combine to counteract organizational learning and homogenization of practices in this field.

Keywords: collaboration, procurement, policy, public clients, project partnering

INTRODUCTION

Today, many very large infrastructure projects are carried out by public clients in urban environments. Such projects are generally subject to high uncertainty and both technically and organizationally complex. To tackle these challenges, clients in many countries world-wide apply new, collaborative contracting models that involve contractors earlier in the process. However, relational contracting also presents substantial challenges to existing practices, competence structures and culture within all organizations involved (Chen et.al 2018, Bygballe and Swärd 2019). In particular, collaborative practices as well as project outcomes have been found to vary widely (Hartmann and Bresnen 2011). Even so, Kuitert *et al.,* (2018) found that public sector clients perceived reliability, and to be predictable in relation to suppliers, as vital for their practice. This indicates that there is a need for more structured learning regarding collaborative contracting in the infrastructure construction sector. Less variation and increased predictability would be favourable especially in large infrastructure projects with high risks.

[1] lilly.rosander@abe.kth.se

Rosander, L and Kadefors, A (2019) From Project to Policy: Implementing a Collaborative Procurement Strategy in a Public Client Organization *In:* Gorse, C and Neilson, C J (Eds) *Proceedings of the 35th Annual ARCOM Conference,* 2-4 September 2019, Leeds, UK, Association of Researchers in Construction Management, 750-759.

General research on projects has often emphasized the unique character of projects and the need to adapt project practices to a specific context as it unfolds over time (Lundin and Söderholm 1995). In construction in particular, decentralization is high and top management often face resistance when implementing their policies in projects (Bresnen *et al.,* 2004). Accordingly, project managers have considerable freedom to initiate and test new practices, while structures to evaluate and spread them between projects are traditionally weak (Dubois and Gadde 2002). Nevertheless, research has established that new project practices may be developed through exploration and situated learning in so called "vanguard projects", but that learning between projects requires that organizational-level structures are put in place for this purpose (Brady and Davies 2004).

Most large infrastructure clients are public authorities and consequently affected by general policy trends. General theories on policymaking may thus provide a complementary perspective on the interaction between high-level policies and project-level practices in this field. In many OECD countries the so called "New Public Management" reform have resulted in new forms of governing, based on increased use of contracts and policies to assure governmental tasks (Lane 2000). Accordingly, the general trend for public clients is to place more responsibility on contractors (Kuitert *et al.,* 2018). In this paper, we build on such observations and analyse collaborative contracting as a case of policy implementation. The empirical basis is a study of a new collaborative Early Contractor Involvement approach (ECI) in two sub-projects in a large Swedish infrastructure project. We identify key implementation issues using a framework based on policy implementation literature and discuss the implications for organizational and industry level learning.

The concept of ECI has several definitions in the construction procurement literature. First, ECI may refer to established models for relational contracting, often in two stages (Farshid *et al.,* 2018, Mosey 2009). The ECI model used in the case study projects is based on this type of two-stage model. However, other authors and approaches define ECI as simply engaging the contractor earlier to profit from their competence with no ambitions of a more profound collaboration (Wondimu *et al.,* 2018).

THEORETICAL FRAMEWORK

Since policy implementation emerged as an explicit research area in the 1970s it has developed into several streams. In traditional, top-down approaches the focus is on the effects of centrally established goals, while the more interpretive bottom-up perspectives deal with how policy definition and outcomes are affected by individual behaviour and sense-making of implementors (Lane 1983, Van Hulst and Yanow 2014). The concept of "street-level bureaucracy" (Lipsky 1980) has been prominent to explain policy-making and implementation in areas where administrative behaviour relies heavily on the professional judgement of the public officers executing policy. The field has later moved towards a more pluralistic view, acknowledging that policy implementation processes are context dependent and often affected by a mix of top-down and bottom-up dimensions (O'Toole 2000). Further, the factors considered to influence the implementation process, primarily relating to organizational resources, individual values and coherence in policy translation, are similar in both streams of literature (Hill and Hupe 2014, Fernandez and Rainey 2006). Policy studies tend to move beyond the more or less simplistic models or frameworks for "success" and look at implementation as a complex and dynamic process, dependent on the capacity of

the organization to identify more in detail which organizational routines and structures will be involved in translating policy to action (Hill 2005). However, factors such as organizational resources, individual values and coherence in policy translation remain important features which are often underestimated or overlooked by organizations (Fernandez and Rainey 2006).

For the purpose of this study, we therefore suggest a framework based on four dimensions inspired by Van Meter and Van Horn (1975) and subsequent studies in the field (cf Fernandez and Rainey 2006 for an overview): Explicitness of policy, Individual and group motivation, Organizational resources and Characteristics of the implementing organizations.

Explicitness of the policy

Unambiguous directives and a cohesive plan for the change is in general perceived to facilitate policy implementation (Fernandez and Rainey 2006). A clear policy is a help for implementing officials as it describes more in detail how the new policy should be incorporated into the agency's operating procedures. However, policymakers may still prefer less explicit policies, for example when they perceive professional implementors to be more competent to choose the means to accomplish policy objectives (Lane 1983), or when the policy is a result of compromise at a political level (Matland 1995). In effect, one of the characteristics of public organizations is that they serve several public values that might compete (Brunsson and Adler, 2002). This may result in policy clashes that create ambiguities and reduce explicitness.

Individual and group motivation

This dimension comprises the motivation and incentives of implementors to enact the policy. When aggregated to the organizational level, these aspects constitute what is often described as “implementation climate”. Thus, Schneider (1990) emphasizes the employees' perceptions of “the events, practices, and procedures and the kinds of behaviours that are rewarded, supported, and expected in a setting”. Especially when individuals and groups are trusted with high authority to make decisions or carry out activities that contribute to policy goals, implementation is facilitated if the actor's own values align with policy objectives (Lane 1983, Fernandez and Rainey 2006).

Organizational resources

One general agreement in the implementation literature has to do with the importance of organizational resources in order to ensure technical and administrative capacity to achieve objectives (O'Toole 2000, Fernandez and Rainey 2006). Resources may be of a “liquid” type, like staff, but also capacity building resources, like training, guidelines, etc. (Schneider and Ingram 1990). It is important to acknowledge that these resources also have a symbolic value, since implementors may use resource allocation as an indication of the true priorities of top management (Matland 1995).

Characteristics of the implementing organizations

Traditionally this dimension addressed the hierarchical relationships between the policy-formulating and the policy-implementing bodies and units, including the ability to enforce policy and sanction non-compliance (Van Meter and Van Horn, 1975). By international comparison, the Swedish policy context and public administration is generally characterized by high autonomy and the relationship between political decisions and the execution of administrative tasks by officers is often described as “government by trust” (Jacobsson *et al.,* 2015, Hill 2005).

METHOD

The two projects studied are two schemes within a large complex urban railway infrastructure project. The project is divided into six major contracts, and for two of the large civil engineering contracts the ECI model was selected. The railway project had a total estimated project budget of 24 billion SEK (2.4 billion Euros), and the estimated costs of the two projects studied were 300 MEUR and 425 MEUR. The study is based on a total of 24 semi-structured interviews that were conducted in two sets, the first during Stage 1 of the project (January-March 2017) and the second after the contracts for Stage 2 were signed (November 2018-January 2019). Interview respondents were project managers from the STA and contractors, responsible design project managers and collaboration facilitators for each project. The flexibility in semi-structured interviews, as described by Kvale (2008) allowed for the interviewees' individual concerns to be addressed. Interviews lasted between one and two hours and were recorded and transcribed. To triangulate the interview findings, project documentation such as procurement strategy documents, collaboration agreements, contracts and tendering documents were investigated.

In the next section, findings are structured according to the chronological process of establishing and implementing the procurement model. Results are then summarized and further discussed based on the analytical model presented in the previous section.

THE CASE

Procurement Model

The two projects studied here were the first within the STA to be procured with an ECI model. The initiative was taken by the STA Project Director, who wished to avoid that the two most complex contracts of this project became as conflict-ridden as his previous project. Together with the Procurement Manager, he consulted widely with European contractors and found them positive to a collaborative approach. Higher STA management approved the idea and the project developed tendering documents for Early Contractor Involvement contracts in the two most complex and uncertain subprojects. Key contractual and organizational features of the ECI model as it was set out in the tendering documents are summarized in Table 1.

Table 1: Features in the ECI-model as described in tendering documents

Procurement procedure and criteria	Restricted procurement procedure with prequalification. Award mechanism "most economically advantageous tender", where quality criteria and price were weighted 70/30 percent.
Early involvement of contractor	Stage 1: the contractor is engaged on a cost-reimbursable consultancy contract. Target cost is developed jointly by the parties. Stage 2: the contractor is reengaged with a Design-Build contract by option.
Reward system	Stage 1: Cost reimbursable consultancy contract. Stage 2: tendered contractor's fee (between 7-12%) plus gainshare/painshare incentive in relation to target cost developed in Stage 1. 50/50 sharing ratio.
Partnering approach	Collaborative organization and collaboration group with defined members Requirements to develop joint project goals, risk management methods, communication plan and conflict resolution methods Continuous project follow-ups Openness in questions of mutual importance Collaborative activities (team building, workshops, etc.) Co-location

The model implies that two separate contracts are set up for Stage 1 and Stage 2. In Stage 1, the contractor is engaged by a consultancy contract and reimbursed based on incurred costs. Provided that the client finds the design and target price acceptable, the contractor is re-engaged by a Design-Build contract to accomplish detailed design and construction. The reward system for Stage 2 is a target cost contract with a gainshare/painshare arrangement.

A few processes and organizational aspects were specified more in detail in the tendering documents. However, since the Project Director and his group believed that the contractors would be more experienced in collaborative contracting than the client, and also wished to use a proposed collaboration plan as a selection criterion, STA chose not to develop the collaboration model more in detail before procuring contractors.

The procurement model for the two pilot cases inspired and influenced a new STA procurement strategy for collaborative projects that was developed by central purchasing department during the same period in time. This work was carried out by two procurement officers working part time. Since the STA was established in 2010 by a merger of the Road and Rail Administrations the focus had been on an increased use of Design-Build contracts and less involvement of the client in line with a so-called "pure client" policy. In this perspective the interest in collaborative contracting was new, although the former Road Administration had a history of working with collaborative approaches, primarily within traditional contracts.

Further implementation and experiences

When the top responsible managers of the two engaged contractors were interviewed in Stage 1 they were enthusiastic that the STA had decided to use the ECI model. They stated that it was essential that these pilot projects would succeed, since the STA otherwise might abandon this procurement model. However, ECI was a new type of collaborative arrangement which presented all participants with many challenges. Some challenges were common to both pilot projects, but since the collaboration models and participants differed between the contracts there were also differences.

Collaboration

The winning contractor for the ECI 1 contract did not have their own collaboration model and had not defined the model in much detail in the tender. However, the contractor's key project managers were experienced and highly regarded for their collaborative competencies by their own organization. The client project manager was young and less experienced but had a positive attitude to collaboration. Thus, new routines and practices were developed in collaboration between the STA, the contractor and the design consultant after the contract was signed. The parties jointly appointed an external partnering facilitator, held a start-up meeting and formulated mutual objectives. Design collaboration was successful: A design consultant came up with an idea for a major design change that solved several problems in the original design and there were numerous smaller design-based improvements.

The contractor of ECI 2, as a company, had a high profile in collaborative contracting. They had a standard collaboration model and an experienced internal facilitator had been involved in developing the tender. However, the project did not follow through the ambitious collaboration plan outlined in the tender. One reason was that time was shorter than planned due to an appeal to court. Moreover, it turned out that several project managers on both sides did not consider relationship-building activities important. After some months, the contractor's project manager was replaced due to

poor soft skills and eventually also two assistant project managers on the client side. Thus, motivation to work in collaboration varied between the two contracts, especially among project managers. However, operational level employees in general appreciated working in a more collaborative way, and perceived that their competence increased through the closer contact with other disciplines.

The size of the client organization in the contracts did not differ from that in a normal project of a similar size. Especially in ECI 1, where collaboration was established as intended, insufficient client resources were perceived to be a major obstacle to efficient decision-making. Both contractors had expected more of a joint project management and emphasized that the client has an important role in "greasing the wheels" of the decision processes and facilitate for other parties to perform their work. Some STA representatives agreed that they should have an active role and regretted the lack of resources. Others however expressed that they expected the contractor to take on a leading role and use their freedom and competencies to provide the project with better solutions. As one STA interviewee said "we gave them a white paper and said - go ahead". Thus, the client representatives had expected skilled contractors with organizational resources that would make them suited to lead design processes in Stage 1. The contractors, on the other hand, expected the STA to step up in situations where they were more experienced, such as design management.

Target cost, incentives and negotiations

Another area of uncertainty and conflict regarded the economic incentives, defined by the contractors' fee, target price and sharing ratio. Both contractors had tendered the minimum fee of 7% despite that they claimed it was too low to cover their costs. The contractors therefore needed to bring profit from the gainshare/painshare scheme, which meant that they had an incentive to inflate the target cost. Managers from both contractors perceived these economic incentives as problematic: "Focus is transferred from collaboration and the project towards guarding the target price" as one contractor project manager put it. The financial incentives also contributed to client distrust. Both subprojects experienced difficulties in defining integrated processes to develop a target cost, and the level of transparency provided by the contractors was questioned. The process resembled a traditional price negotiation and contracts for Stage 2 were signed with a delay of more than nine months. To reduce the contractors' risks, the sharing ratios were eventually adjusted to 90/10 for ECI 1 and 80/20 for ECI 2.

Stage 1 output and responsibilities

Unclear contractual responsibilities were highlighted by interviewees from both sides. It was not explicitly defined what responsibility the contractors had for the technical design developed during the consultancy contract of Stage 1, but the STA insisted that the contractors should have the full responsibility for decisions since they were to be engaged by a Design-Build contract in Stage 2. The first round of interviews (in Stage 1) also revealed that managers on the contractor's side, including design managers, were uncertain about the level of detail in the design documents to be delivered at the end of Stage 1. In the second round of interviews project managers on both sides perceived the lack of explicit definition of the delivery content as a major cause of the prolonged negotiations of the target cost.

DISCUSSION

In this section, we discuss key features of the case in relation to the theoretical framework of policy implementation (summarized in Table 2).

Explicitness of policy

Overall, there were substantial ambiguities and uncertainties regarding processes, systems, roles and outputs relating to the collaborative model. Policy design and implementation at a detailed level was strongly influenced by individual interpretations and preferences (Lane 1983, Van Hulst and Yanow 2014), resulting in substantial differences between the two projects. To some extent this lack of explicitness could be explained by the pilot character of the cases, since the participants gradually became aware of the implications of the new policy on a more detailed level (cf Hill 2005). However, no substantial attempts were made to clarify these issues to inform further development of the model. Inexplicitness was also intentional: since the client wished to use the contractor's collaboration plan as a selection criterion models would vary between projects based on contractor input. Further, by not defining key issues jointly, client involvement was reduced and responsibility moved to the market, in line with the pure client policy and current policy trends (Lane 2000, Jacobsson et.al. 2015). Thus, this inexplicitness could be seen as a result of competing values and policies within the STA (Brunsson and Alder 2002). Tendering documents, initial communications and some of the managers on both sides emphasised collaboration and shared risks, while others, including the Project Director and one of the client sub-project managers, stressed that early involvement primarily implies a transfer of influence and responsibilities to the contractor. This ambiguity also mirrored the different interpretations of the ECI concept described in the literature (Wondimu *et al.,* 2018).

Motivation

Motivation to implement the new model varied between individuals and organizational levels. In general, the actors initially expressed high motivation and expectations on the new procurement approach, but the many challenges and different understandings of roles and responsibilities successively hampered motivation. The client did not select their personnel based on their collaboration skills and there was a lack of strong collaboration champions engaging in the relational dimensions of the model. In ECI 2, personnel on both sides were replaced due to relational issues. The contractual incentives constituted a motivational problem as well, since the contractors had to balance between their organizational motives and a will to create a good project (Matinheikki *et al.,* 2019). Due to the ambiguities and inexplicitness of the policy it was not easy for the actors to interpret which behaviours were expected from them (Van Hulst and Yanow 2014).

Resources

Resources was a key question in both sub-projects. Literature on relational contracting suggests that the client should take a more active role (Chen et.al 2018), and the contractors' expectations on the client to more actively support the design management and be involved in setting the target cost aligned with this view. However, the Project Director believed that appointing additional resources to engage in joint decision-making would be against the pure client policy. Further, despite that the two pilot sub-projects were initially considered to be industry-level game changers, central functions at the STA to support collaborative contracting were small and none of the organizations educated their staff in collaborative practices in advance. Lack of resources to support implementation, such as detailed guidelines and training related to collaborative contracting, did not only impact on the capacity of project participants to achieve collaborative performance (Fernandez and Rainey

2006) but could also be perceived by the implementors as an indication that this policy was not important (Schneider and Ingram 1990, Matland 1995).

Characteristics of the STA - a public project-based organization
Since the initiative to explore a new procurement strategy came from the project level, it can be seen as a bottom up policy implementation. However, the initiative had high level support within STA and a central strategy for collaborative contracting was being developed in parallel. The two pilot projects were initially pictured as "vanguard" projects, where new practices could be developed and tested as a basis for further implementation as described by Brady and Davis (2004), but in practice the learning process was unclear. The responsible procurement officer followed the pilot projects but had no authority to intervene and, for example, provide training or help the project clarify the ambiguities. The absence of a clear learning strategy reflects not only competing policies as described above, but also the traditionally high project autonomy and corresponding limitations to inter-project learning (Bresnen *et al.,* 2004, Hartmann and Bresnen 2011) as well as the Swedish preference for "government by trust" and high autonomy of public officers (Jacobsson *et al.,* 2015, Lipsky 1980).

Table 2: Summary of the case features categorized according to the theoretical framework

Implementation dimension	Key observations
Explicitness of policy	Unclear roles of the parties in creating collaborative structures and involvement in collaboration.
	Processes for setting target cost and financial transparency not defined.
	Detail of design output and design responsibility in Stage 1 were not defined.
Motivation	Mainly high motivation at higher management levels, but no experienced collaboration champions in key positions.
	Varying motivation among project managers at all levels but positive attitude to collaboration at operational (designing engineer) level.
	Financial incentives established to motivate yet perceived more as obstacles.
Resources	Partnering facilitators and joint premises for co-location.
	No additional STA resources to engage in collaboration.
	Small resources for central support from the STA.
	Few key actors had training in collaboration.
	Contractors had insufficient resources to manage design.
Characteristics of organization	A lot of details were left to the project and sub-projects to handle.
	Collaboration atmosphere, processes and results differed significantly between the sub-projects.
	National management levels did not interfere and follow up.

CONCLUSIONS

Collaborative contracting models are increasingly used by client organizations to tackle complexity and uncertainty in large infrastructure construction projects. In order to deliver high quality infrastructure, it is important to understand not only success factors and risks in implementing a new model, but also how experiences can be captured and used to inform industry level learning in this field. In this study, we apply a framework based in research on public administration to analyse the implementation of a new collaborative procurement policy in the Swedish Transport

Administration. The experiences were mixed: the model enabled major improvements and adaptations but was also associated with ambiguities and conflicts.

We suggest that key issues in the implementation process may be explained in terms of low explicitness, limited resources and varying motivation to implement the policy. Consequently, a straightforward conclusion would be that a more efficient implementation would require more resources, both on the project level and at central STA functions. Central units at the STA, then, should provide training, monitor projects, develop guidelines and be involved in selecting key project staff. More resources would improve explicitness, signal importance and increase motivation. However, it is obvious that this type of strategy would not be easy to implement due to underlying characteristics of the implementing organization. In particular, inexplicitness in the cases was partly due to policy clashes, were high client involvement in collaboration contradicted the trend towards more responsibility of market actors, as reflected in the "pure client" policy.

Further barriers to explicitness stemmed from the high project-level autonomy in the construction sector. This decentralized governance structure resembles that of "street-level bureaucrats" in other areas of public administration (Lipsky, 1980). There is a high degree of institutionalization of roles and practices in the construction sector as well (Kadefors 1995), but these common frames of reference do not extend to detailed levels of collaborative contracting. This study supports the view that increased homogeneity and predictability would be valuable (Kuitert *et al.,* 2018), and also that large public infrastructure client have a key role in establishing - or impeding - such institutionalization of collaborative practices.

REFERENCES

Brady, T and Davies, A (2004) Building project capabilities: From exploratory to exploitative learning, *Organization Studies*, 25(**9**), 1601-1621.

Bresnen, M, Goussevskaia, A and Swan, J (2004) Embedding new managements knowledge in project-based organizations, *Organization Studies*, 25(**9**), 1535-1555.

Brunsson, N and Adler, N (2002) *The Organization of Hypocrisy: Talk, Decisions and Actions in Organizations*. Malmö: Liber.

Bygballe, L E and Swärd, A (2019) Collaborative project delivery models and the role of routines in institutionalizing partnering, *Project Management Journal*, 50(**2**), 161-176.

Chen, L, Manley, K, Lewis, J, Helfer, F and Widén, K (2018) Procurement and governance choices for collaborative infrastructure projects, *Journal of Construction Engineering and Management*, 144(**8**), 04018071-10.

Dubois, A and Gadde, L-E (2002) The construction industry as a loosely coupled system: Implications for productivity and innovation, *Construction Management and Economics*, 20(**7**), 621-631.

Farshid, R, Malik, M A K and Tayyab, M (2018) A comparative study of early contractor involvement and project alliancing, *International Journal of Project Organization and Management*, 10(**2**), 93-108.

Fernandez, S and Rainey, H G (2006) Managing successful organizational change in the public sector, *Public Administration Review*, 66(**2**), 168-177.

Hartmann, A and Bresnen, M (2011) The emergence of partnering in construction practice: An activity theory perspective, *Engineering Project Organization Journal*, 1(**1**), 41-52.

Hill, M and Hupe, P L (2014) *Implementing Public Policy: An Introduction to the Study of Operational Governance*. Los Angeles: SAGE.

Hill, M (2005) *The Public Policy Process*. Malaysia: Pearsons Education Limited.

Jacobsson, B, Pierre, J and Sundström, G (2015) *Governing the Embedded State: The Organizational Dimension of Governance*. Oxford: Oxford University Press.

Kadefors, A (1995) Institutions in building projects: Implications for flexibility and change, *Scandinavian Journal of Management*, 11, 395-408.

Kuitert, L, Volker, L and Hermans, M H (2018) Taking on a wider view: Public value interests of construction clients in a changing construction industry, *Construction Management and Economics*, 37(**5**), 257-277.

Kvale, S (2008) *Doing Interviews*. London: SAGE Publications. .

Lane, J-E (1983) The Concept of Implementation, Statsvetenskaplig Tidskrift, 86(**1**), 17-40.

Lane, J-E (2000) *New Public Management: An Introduction*. London: Routledge.

Lipsky, M (1980) *Street-Level Bureaucracy: Dilemmas of the Individual in Public Services*. New York: Russell Sage Foundation.

Lundin, R A and Söderholm, A (1995) A theory of the temporary organization, *Scandinavian Journal of Management*, 11(**4**), 437-455.

Matinheikki, J, Aaltonen, K and Walker, D (2019) Politics, public servants and profits: Institutional complexity and temporary hybridization in a public infrastructure alliance project, *International Journal of Project Management*, 37(**2**), 298-317.

Matland, R E (1995) Synthesizing the implementation literature: The ambiguity-conflict model of policy implementation, *Journal of Public Administration Research and Theory*, 5(**2**), 145-174.

Mosey, D (2009) *Early Contractor Involvement in Building Procurement Contracts, Partnering and Project Management*. Hoboken, NJ: John Wiley and Sons, Ltd.

O'Toole, L J (2000) Research on policy implementation: Assessment and prospects, *Journal of Public Administration Research and Theory*, 10(**2**), 263-288.

Schneider, B (1990) *Organizational Climate and Culture*. San Francisco: Jossey-Bass.

Schneider, A and Ingram, H (1990) Behavioural assumptions of policy tools, *The Journal of Politics*, 52(**2**), 510-529.

Van Hulst, M and Yanow, D (2014) From policy frames to framing: Theorizing a more dynamic, political approach, *The American Review of Public Administration*, 46(**1**), 92-112.

Van Meter, D S and Van Horn, C E (1975) The policy implementation process: A conceptual framework, *Administration and Society*, 6(**4**), 445-488.

Wondimu, P A, Hosseini, A, Lohne, J and Laedre, O (2018) Early contractor involvement approaches in public project procurement, *Journal of Public Procurement*, 18(**4**), 355-378.

QUALITY

DETERMINANTS OF WORKMANSHIP: DEFINING QUALITY IN CONSTRUCTION INDUSTRY

Sparsh Johari[1] and Kumar Neeraj Jha

Department of Civil Engineering, Indian Institute of Technology Delhi, Hauz Khas, New Delhi, 110016, India

Quality is one of the key objectives of any project. To achieve good quality, workmanship is an important factor to consider. However, very few studies have explored the causes of poor workmanship in the past. Hence, this research aims to identify the determinants of workmanship affecting the quality of the construction work at the sites. To achieve this, first, the literature review was carried out, and 10 determinants were identified. Subsequently, key determinants were determined through two independent investigations covering industry professionals (top-down approach) using the Delphi technique, and the construction workers (bottom-up approach) using a questionnaire survey technique. The results found five key determinants; and, reveal the differences in the opinion of the construction workers from the industry professionals. The results will help the training providers to train the workers specifically on the improvement of the identified determinants of workmanship to resolve the problem of poor quality of construction work.

Keywords: workers, Delphi technique, quality, training, workmanship

INTRODUCTION

In comparison to the other industries, the construction industry is always criticised for its poor performance, productivity and quality (Nesan and Holt, 1999; Oglesby *et al.,* 1989). The construction industry is constantly under the scrutiny for the quality of work (Loushine *et al.,* 2006).

Therefore, to improve the quality in construction, studies in the past have identified various factors that affect the quality of the construction work (Atkinson, 1998; Maloney, 2002; Pheng and Wee, 2001). Some of the factors are poor workmanship, use of unsuitable equipment, use of low-quality materials, lack of supervision, etc. However, out of all these factors, workmanship was found as the most decisive factor to achieve good quality in the construction work (Durdyev *et al.,* 2017; Hoonakker *et al.,* 2010; Love *et al.,* 1999; Mailvaganam and Collins, 2004; Ng *et al.,* 2004). This is because the workmanship is an interface between the materials, equipment, and the executed work.

Although many studies have found the importance of good workmanship for achieving a good quality of work; not much emphasis was given for improving it in the past. Tam *et al.,* (2000) showed that the expected continued improvement in construction quality had not been realised. This is because of the lack of standardisation and empirical knowledge, which makes it difficult to implement the

[1] sparshjo@gmail.com

Johari, S and Jha, K N (2019) Determinants of Workmanship: Defining Quality in Construction Industry *In:* Gorse, C and Neilson, C J (Eds) *Proceedings of the 35th Annual ARCOM Conference,* 2-4 September 2019, Leeds, UK, Association of Researchers in Construction Management, 761-770.

workmanship principles in the construction industry. Therefore, it is essential to identify those determinants of workmanship associated with the construction workers which impact the quality of the construction work at the sites (Małachowski and Korytkowski, 2016).

This study has focused on the identification of those determinants of workmanship which affects the quality of the construction work executed by the workers at the sites. This aim was achieved in two steps. First, the literature review was carried out, and 10 determinants were identified. In the second step, five key determinants were ascertained from the identified determinants through two independent and parallel investigations covering industry professionals (top-down approach) and the construction workers (bottom-up approach) as experts. Identification of these determinants will help the training providers to strategically alter the existing training curriculum for the workers to focus specifically on the improvement of these key determinants of the workers during training. This eventually would help the industry to resolve the problem of poor quality of construction work at the sites.

LITERATURE REVIEW

Workmanship is defined as a human attribute relating to knowledge and skills at performing a task. This indicates that skill level will influence the quality of workmanship, which in turn can have a positive or negative influence on rework and project costs (Love *et al.,* 1999).

To measure workmanship, researchers have found cost-to-rework as a quantification tool (Durdyev *et al.,* 2017; Durdyev and Mbachu, 2011; Tripathi and Jha, 2017a). Similarly, customer centricity and cost-to-waste were also found as a quantification tool to measure the level of workmanship (Hoonakker *et al.,* 2010; Maloney, 2002; Sommerville, 1994). However, before measuring the level of workmanship, it is essential to identify factors which influence the workmanship.

Mailvaganam and Collins (2004) studied the influence of workmanship on the installation of elastomeric waterproofing membranes. They found that the durability of the final product does not only depend upon the material properties but also on the workmanship. The study established that due to the lack of on-site practice, the workers often adopt wrong working procedures while working, which leads to the delivery of the poor-quality product.

Similarly, Tam and Fung (2012) emphasised on safety while working. They showed that by adopting necessary safety measures during the work, the workers deliver a high level of performance at the sites. This is because their motivation level and morale remain high by using safety measures while working. Along with this, team working skills among the workers were also identified as a significant factor influencing productivity and quality of construction work at the site. Jayasinghe and Fernando (2017) displayed that the team working skills among the workers influences their efficiency; and thus, can be considered as a determinant of workmanship.

In line with the previous studies, Wang *et al.,* (2008) examined the influence of construction craft training and absenteeism on the performance of construction workers in construction firms of the USA. The results revealed that training has a positive influence on the workers. Their performance got improved by reducing absenteeism. Similarly, using the right tools and tackles while working was also found as a significant factor influencing workmanship at the site (Bubshait and Al-Atiq, 1999).

Sommerville (1994) indicated that wastage of material and time while working shows the incompetency of a worker. This influences their performance and thus affects the quality and productivity of the work. Hence, wastage of material and time while working can also be considered as the determinants of workmanship.

From the referred literature, it has been observed that workmanship is an important factor that affects the quality of construction work. However, very few studies have identified the factors influencing the workmanship at the sites. Moreover, those few studies have used top-down approaches for deriving the results. None of the studies has validated the results by using a bottom-up approach. Hence, it is important for the research community as well as the industry to consider the opinion of the construction workers in identifying the determinants of workmanship in order to increase the quality of construction work at the site.

RESEARCH OBJECTIVE

The two key research objectives are as follows:

- To identify the determinants of workmanship
- To establish the key determinants of workmanship

RESEARCH METHOD

The overall research method consists of three steps. These steps are explained in detail in the following sub-sections.

Step 1: Identification of Determinants of Workmanship

By using relevant sources of literature, nine determinants of workmanship were identified that determine the quality of construction work at the site. To check the exhaustiveness/ completeness of the list of these identified determinants for the construction industry, the list of the determinants was personally discussed with three experts. These three experts included one project manager, one project engineer and an experienced construction worker. Each of these experts had more than 15 years of experience in the construction industry. The experts suggested incorporating three more determinants, namely, fickle profession, housekeeping, and task planning to make the list exhaustive. Also, the experts suggested to remove two determinants - cost to rework and user satisfaction - as both of them are the measure of workmanship rather than the determinants. Therefore, after incorporating the suggestions of the experts, a total of 10 determinants were finalised as shown in Table 1.

Step 2: Data Collection

The data was collected from two sources using two different techniques: (i) from industry professional (top-down approach) using Delphi technique, and (ii) from construction workers (bottom-up approach) using questionnaire survey technique. Participants of both groups (industry professionals and construction workers) were working in the Indian construction industry. These two data sources are explained in the following subsections:

Data collection from industry professionals using Delphi technique (top-down approach)

Hallowell and Gambatese (2010) recommended the use of the Delphi method for obtaining a reliable consensus of opinion of experts. The construction skill development council under the Ministry of skill development and entrepreneurship is responsible for developing training standards for the construction workers in India.

These training standards are developed by the 15-member panel of experts who are working as top professionals in various leading construction companies in India. All the 15 experts were contacted, however, only twelve agreed to participate in the study. Out of twelve, responses from ten experts were received in person and two responses via email.

Table 1: List of determinants of workmanship

S. No.	Determinant of workmanship	Sources
1	Absenteeism	(Wang *et al.,* 2008)
2	Fickle profession	Experts
3	Following correct working procedures	(Bubshait and Al-Atiq, 1999; Loushine *et al.,* 2006; Mailvaganam and Collins, 2004)
4	Housekeeping	Experts
5	Safety while working	(Loushine *et al.,* 2006; Tam and Fung, 2012)
6	Task planning	Experts
7	Team working skills	(Jayasinghe and Fernando, 2017)
8	Use of right tools and tackles	(Bubshait and Al-Atiq 1999)
9	Wastage of material while working	(Formoso and Revelo, 1999; Loushine *et al.,* 2006)
10	Wastage of time while working	(Formoso and Revelo, 1999; Loushine *et al.,* 2006)

A self-administered questionnaire was designed based on the identified determinants of workmanship. The question which was posed to the professionals was: 'How much impact does each of the determinants make on the workmanship?' A five-point unipolar Likert scale was used to measure this impact, where, 5 = very high impact, 4 = high impact, 3 = moderate impact, 2 = low impact, and 1 = very low impact. The questionnaire was administered in three rounds in the study as explained subsequently.

Round 1: The responses collected from Round 1 were used to rank the attributes according to their mean value. Also, the summary statistics of the responses such as median, interquartile range and standard deviation were calculated. The summary statistics showed wide variation in the responses, hence, round 2 was conducted to bring consensus in the responses.

Round 2: In this round, the median, interquartile ranges and the comments submitted by all the respondents in the first round were sent back to each of the experts. By providing the first-round responses, the authors tried to make the consensus among the responses of the experts in the second round. Also, if the latest response of the experts was not within the consensus range, the authors asked the experts to justify their response briefly. The authors found significant improvement in the consensus range after evaluating the responses of Round 2.

Round 3: As the authors found notable changes in the responses of the experts in Round 2, another round of Delphi was conducted to check further alteration in the responses by the experts. Hence, similar to Round 2, the authors sent the median, interquartile ranges and the comments of Round 2 to the experts. If still, the response of any of the experts was out of the range of the consensus, the authors asked for the justification in brief. However, analysis of Round 3 brought no further changes in the responses of Round 2. Hence, no further rounds were conducted by the authors.

Data collection from construction workers using questionnaire survey technique (bottom-up approach)

An interviewer-administered questionnaire was designed based on the 10 determinants of workmanship as identified in Step 1. The choice of interviewer-administered questionnaire over self-administered questionnaire was made because of the two main

reasons: unavailability of workers' contact details, and the inability of the workers to read and understand the questionnaire by themselves due to illiteracy.

A similar questionnaire, which was used for industry professionals, was applied for data collection purpose from construction workers as-well. A pilot study was then undertaken to test the language and understanding of the questionnaire. According to the suggestions obtained from the pilot study, some major changes were made in the questionnaire to make it more understandable for the workers. The questionnaire consists of two parts. Part 1 included the questions related to the measurement of the impact of determinants on workmanship, and Part 2 consisted of the demographic profile of the respondents.

The authors conducted this interviewer-administered questionnaire survey at five construction sites in and around close vicinity of New Delhi, India. Multi-storey residential buildings were constructed at these sites. The respondents (construction workers) were primarily belonging to three trades: bar-bending, carpentry, and masonry. Also, to communicate with the workers in their local languages, the authors took the help of the supervisors at the site. These supervisors worked as the interpreter for the authors during the questionnaire survey. A total of 86 valid responses were recorded by the authors.

Step 3: Data Analysis

The data were analysed in four parts. In the first two parts, the determinants were ranked based on the data collected through the Delphi technique and the questionnaire survey technique respectively. In the third part, key determinants of workmanship were identified based on the mean value of each determinant. Subsequently, to check the level of agreement between the responses of the industry professionals and the construction workers over the rankings of the determinants, a correlation test was conducted in the fourth part of the data analysis.

Ranking of the determinants obtained from industry professionals
The data was analysed by using the software package SPSS 20. To check the reliability of the data, Cronbach's alpha was determined. It was found to be 0.772 at 5% significance level, which was greater than 0.5. Hence, it confirms the reliability of the data. To measure the consensus in the opinions of the experts, Relative index rating (RIR) was used. The RIR values for all the determinants in all the three rounds were calculated by using Eq. (1). Also, the attributes were ranked based on the mean value obtained from the responses. The ranks of the attributes based on the responses of the industry professionals are shown in Column 4 of Table 2.

$$RIR = \frac{(Q_3 - Q_1)}{\bar{x}} \times 100 \qquad (1)$$

where Q_3 is the third quartile; Q_1 is the first quartile; $\bar{x}$ is the mean.

Ranking of the determinants obtained from construction workers
Based on the responses collected on a five-point Likert scale, the determinants were ranked according to their mean value. However, when the mean value of two or more determinants was found to be the same, the determinant having lower standard deviation was ranked higher than the others (Tripathi and Jha, 2017b). The ranking of the determinants based on the data collected through the questionnaire survey are shown in Column 6 of Table 2.

Table 2: Ranking of the determinants from top-down and bottom-up approaches

S. No.	Determinant of workmanship	Industry professionals		Construction workers	
		Mean	Rank	Mean	Rank
1	Absenteeism	3.917*	2	2.302	10
2	Fickle profession	3.333	6	4.302*	3
3	Following correct working procedures	3.667*	5	4.663*	1
4	Housekeeping	2.917	8	4.070*	5
5	Safety while working	4.167*	1	4.651*	2
6	Task planning	2.833	9	2.988	7
7	Team working skills	3.833*	3	2.978	8
8	Use of right tools and tackles	3.750*	4	2.837	9
9	Wastage of material while working	3.083	7	4.280*	4
10	Wastage of time while working	2.417	10	3.337	6

**Key determinants of workmanship ($\mu \geq 3.5$)*

Identification of key determinant of workmanship

The mean value of the responses obtained from the descriptive statistical analysis was not a whole number. Therefore, for interpretation purpose, the impact of each of the determinant on the workmanship may be considered to lie between mid-points of two adjacent scales (Tripathi and Jha, 2017a). The degree of impact of the determinants with respect to the mean value (μ) greater and equal to 4.5 was considered as very high impact on the workmanship. Similarly, the range of mean values $4.5 > \mu \geq 3.5$ was treated as high impact; $3.5 > \mu \geq 2.5$ as moderate impact; $2.5 > \mu \geq 1.5$ as low impact; and mean value less than 1.5 was treated as very low impact on the workmanship.

Therefore, those determinants of workmanship which lie in the very high and high degree of impact ($\mu \geq 3.5$) were considered as the key determinants of the workmanship in the study.

Formulation of study hypothesis

To check the level of agreement between the ranking of the attributes given by the industry professionals and the construction workers, the following hypothesis was made:

(i) Null hypothesis (Ho): There is no significant correlation between the rankings of the determinants of workmanship given by industry professionals and construction workers.

(ii) Alternative hypothesis (H1): There is a significant correlation between the rankings of the determinants of workmanship given by industry professionals and construction workers.

To test the above hypothesis, Spearman's rank correlation coefficient (R) test was conducted. This test is a nonparametric test and requires rank data. If the values of coefficient R are not statistically significant at an allowable significance level of, say 5%, then the null hypothesis that there is no significant correlation between the rankings of the determinants given by industry professionals and construction workers cannot be rejected. After applying this test, the results revealed that the rankings were not significant at a 95% confidence interval. It shows that there is a difference in the opinion of the industry professionals and the construction workers on defining the determinants of workmanship.

RESULTS AND DISCUSSION

The aim of this study was to identify and evaluate the key determinants of workmanship. The responses collected from the industry professionals revealed five key determinants of workmanship (Table 2 Column 4). These are safety while working, absenteeism, team working skills, use of right tools and tackles, and following correct procedures while working. These are the results obtained by a typical top-down approach most commonly used by many of the studies in the past (Tam and Fung, 2012; Wang *et al.,* 2008), where the industry professionals identify the solutions of the problems associated with the construction workers, and the considerations are imposed on them (Heckman and Rudelius, 2018). In the authors' opinion, however, the construction workers themselves should be in a better position to identify what is best for them. Keeping this in view, the authors used a bottom-up approach to get a deeper insight into the determinants of workmanship. Interestingly, out of five identified key determinants, the construction workers agreed with only two of them (see ranks 1 to 5 in Column 6 of Table 2), namely, safety while working, and following correct procedures while working.

Safety while working is found to be an important determinant of workmanship. More than 60,000 fatal casualties and 200,000 non-fatal casualties are reported every year around the world (Lingard, 2013). This is mainly because of the use of improper and/or incorrect safety equipment while working. Such fatal and non-fatal accidents reduce the motivation level and morale of the workers at the sites (Li *et al.,* 2012), and, ultimately affects the productivity and quality of the work executed by them. Therefore, to execute the work productively with necessary quality, the workers must adhere themselves to the safety norms by using correct safety tools and equipment while working at the sites. Hence, safety while working was found to be a key determinant of workmanship. Likewise, procedures followed by the workers while working at the site also determines their workmanship. This is because any variation or error in the working procedure can result in poor quality of work (Mailvaganam and Collins, 2004), and thus, the knowledge and ability of a worker to use and apply correct procedures while working were found to be important determinants of workmanship.

Along with these two key determinants, the construction workers highlighted additional three key determinants of workmanship which were not reported by the industry professionals. These are fickle profession, wastage of material while working, and housekeeping.

The fickle profession is the lack of constancy or stability of the workers in the construction industry. The long absence of workers from the construction work results in a low-performance output from them after returning to the work (Durdyev *et al.,* 2017). As construction is not the only occupation of most of the workers in the developing countries, they frequently change their profession from construction to agriculture to manufacturing etc. This substantially hampers their working skills after returning to the construction work, and hence, the fickle profession is found as a key determinant of workmanship. Similarly, wastage of material while working was found as another key determinant of workmanship. Wastage of material is an inefficiency of a worker which results in using larger quantities of material than those that required for construction (Koskela, 1992). This implies that the wastage of material is the result of the incompetence of the workers due to their lack of knowledge, skills and attitude, which ultimately results in delivering a poor quality of

work due to poor workmanship. Along with the wastage of materials, while working, the construction workers also highlighted housekeeping as a key determinant of workmanship. Housekeeping is the habit of cleaning and properly arranging and/or disposing of the materials or waste during and after finishing any activity (Leamon and Murphy, 1995). Thus, the habit of housekeeping will not only result in a cleaner workplace but makes it safer as well. This results in reducing illnesses and injuries also while working and promotes a positive attitude and morale among the workers. Therefore, good housekeeping practices during the work help in substantial improvement in the workmanship at the site.

The difference in opinions of industry professionals and construction workers was put to test through the hypothesis testing. The test results confirmed the differences as well as the respective ranks provided to the attributes by the two groups (industry professionals and construction workers). The prime reason for this difference lies in the fact that the workers are directly attached to the job on the regular basis than the professionals, and therefore are more aware of the inadequacies that impede the workmanship. Resultantly, the thought process of both the groups act on a completely different plane. Therefore, in addition to the existing apprenticeship training programs, where, the training curriculum is more or less developed on the basis of professionals thought process, it is imperative to take workers' consideration also.

CONCLUSIONS

Quality is one of the key project objectives in the construction industry. There are many factors that contribute to achieving good quality at the site; workmanship is one of the decisive factors among them. Therefore, this study attempts to find out the key determinants of workmanship affecting quality of the construction work executed by the construction workers at the site.

The five key determinants of workmanship were identified by rendering the responses from industry professionals (top-down approach) through the Delphi technique. These are safety while working, absenteeism, team working skills, use of right tools and tackles, and following correct procedures while working. It is clear that the industry professionals highlighted those determinants which can be improved by improving the practical knowledge and skills of the workers through existing apprenticeship training programs. However, when the authors applied a bottom-up approach by using interviewer-administered questionnaire from the construction workers, interestingly, out of five identified determinants, the workers agreed with only two of them, namely, safety while working, and following correct procedures while working. Along with these two, the construction workers highlighted additional three key determinants of workmanship which were not reported by the industry professionals. These are fickle profession, wastage of material while working, and housekeeping. The emphasis of these determinants is more on the competence of the workers involving behaviour, attitude and motivation of the workers rather than solely on their working knowledge and skills. This drew an important conclusion that, along with the knowledge and skills of the workers, their competence level gets affected by their behaviour, attitude and motivation also, which in turn affects the workmanship, which needs to be enhanced. Therefore, in addition to the existing apprenticeship training programs, where, the training curriculum is more focused on improvement of the practical knowledge and skills of the workers; training programs are also required to upgrade the workers' behaviour, attitude and motivation which if not taken care, subtly affects even the positive output gained from enhanced skills and knowledge.

Further research is needed to develop the quantitative indices for each of the determinants in order to quantify workmanship, which eventually would help in developing competency-based training programs for the workers. This might prove to be a valuable research.

REFERENCES

Atkinson, A (1998) Human error in the management of building projects, *Construction Management and Economics*, 16(**3**), 339-349.

Bubshait, A A and Al-Atiq, T H (1999) ISO 9000 Quality standards in construction, *Journal of Management in Engineering*, 15(**6**), 1189-1201.

Durdyev, S and Mbachu, J (2011) On-site labour productivity of New Zealand construction industry: Key constraints and improvement measures, *Australasian Journal of Construction Economics and Building*, 11(**3**), 18-33.

Durdyev, S, Omarov, M and Ismail, S (2017) Causes of delay in residential construction projects in Cambodia, *Cogent Engineering*, 4(**1**), 1-12.

Formoso, C T and Revelo, V H (1999) Improving the materials supply system in small-sized building firms, *Automation in Construction*, 8(**6**), 663-670.

Hallowell, M R and Gambatese, J A, (2010) Qualitative research: Application of the Delphi method to CEM research, *Journal of Construction Engineering and Management*, 136 (**1**), 99-107.

Heckman, J J and Rudelius, T (2018) Top down approach to 6D SCFTs, *Journal of Physics A: Mathematical and Theoretical*, 52(**9**).

Hoonakker, P, Carayon, P and Loushine, T (2010) Barriers and benefits of quality management in the construction industry: An empirical study, *Total Quality Management and Business Excellence*, 21(**9**), 953-969.

Jayasinghe, R S and Fernando, N G (2017) Developing labour productivity norms for aluminium system formwork in Sri Lanka, *Built Environment Project and Asset Management*, 7(**2**), 199-211.

Koskela, L (1992) *Application of the New Production Philosophy to Construction*. Stanford: Stanford University.

Leamon, T B and Murphy, P L (1995) Occupational slips and falls: More than a trivial problem, *Ergonomics*, 38(**3**), 487-498.

Li, H, Chan, G and Skitmore, M (2012) Multiuser virtual safety training system for tower crane dismantlement, *Journal of Computing in Civil Engineering*, 26(**5**), 638-647.

Lingard, H (2013) Occupational health and safety in the construction industry, *Construction Management and Economics*, 31(**6**), 505-514.

Loushine, T W, Hoonakker, P L T, Carayon, P and Smith, M J (2006) Quality and safety management in construction, *Total Quality Management and Business Excellence*, 17(**9**), 1171-1212.

Love, P E D, Manual, P and Li, H (1999) Determining the causal structure of rework influences in construction, *Construction Management and Economics*, 17(**4**), 505-517.

Mailvaganam, N P and Collins, P G (2004) Workmanship factors influencing quality of installed parking garage waterproofing membranes, *Journal of Performance of Constructed Facilitie*s, 18(**3**), 121-127.

Malachowski, B and Korytkowski, P (2016) Competence-based performance model of multi-skilled workers, *Computers and Industrial Engineering*, 91, 165-177.

Maloney, W F (2002) Construction product / Service and customer satisfaction, *Journal of Construction Engineering and Management*, 128(**6**), 522-529.

Nesan, L J and Holt, G D (1999) *Empowerment in Construction: The Way Forward for Performance Improvement*. Baldock, Hertfordshire: Research studies press.

Ng, S T, Skitmore, R M, Lam, K C and Poon, A W C (2004) Demotivating factors influencing the productivity of civil engineering projects, *International Journal of Project Management*, 22(**2**), 139-146.

Oglesby, C H, Parker, H W and Howell, G A (1989) *Productivity Improvement in Construction*. New York: McGraw-Hill.

Pheng, L and Wee, D (2001) Improving maintenance and reducing building defects through ISO 9000, *Journal of Quality in Maintenance Engineering*, 7(**2**), 6-24.

Sommerville, J (1994) Multivariate barriers to total quality management within the construction industry, *Total Quality Management*, 5(**5**), 289-298.

Tam, C M, Deng, Z M, Zeng, S X and Ho, C S (2000) Quest for continuous quality improvement for public housing construction in Hong Kong, *Construction Management and Economics*, 18 (**4**), 437-446.

Tam, V W Y and Fung, I W H (2012) Behaviour, attitude and perception toward safety culture from mandatory safety training course, *Journal of Professional Issues in Engineering Education and Practice*, 138(**3**), 207-213.

Tripathi, K K and Jha, K N (2017a) An empirical study on performance measurement factors for construction organizations, *KSCE Journal of Civil Engineering*, 22(**4**), 1052-1066.

Tripathi, K K and Jha, K N (2017b) Determining success factors for a construction organization: A structural equation modelling approach, *Journal of Management in Engineering*, 34(**1**), 04017050.

Wang, Y, Goodrum, P M, Haas, C T and Glover, R W (2008) Craft training issues in American industrial and commercial construction, *Journal of Construction Engineering and Management*, 134(**10**), 795-803.

STRATEGY

COMPETITIVE STRATEGIES IN SMALL AND MEDIUM SIZED ENTERPRISES (SME'S): A CROSS-CASE ANALYSIS OF IRISH CONSTRUCTION PROFESSIONAL SERVICE FIRMS

Oluwasegun Seriki[1] and Róisín Murphy

School of Surveying and Construction Management, Technological University Dublin, City Campus, Dublin 1, Ireland

Strategy formulation aims to attain strategic fit between an organisation and its business environment in pursuit of competitive advantage. Although competitive strategy research is long established within industries such as manufacturing, financial services and IT, strategy within construction is still under-investigated by comparison. For construction professional service firms (CPSFs), the dearth of academic inquiry is even more apparent, partly due to the intangible nature of their service offerings, highly customised nature of their services and reliance on intellectual capital. The Irish construction sector is experiencing stable growth since following a prolonged recession, thus understanding the strategy process within professional service firms is becoming increasingly important given the role of the service sector in economic recovery. Although the overwhelming majority of Irish CPSF's are small-sized, there remains a paucity of evidence pertaining to the competitive strategies adopted by Small and Medium Size Enterprises (SME's) within construction. This study is a cross-professional investigation involving architectural, engineering and surveying (AES) firms. These firms work together in the interest of the client on a project-level yet may select different strategic options and are led by different types of strategists. The aim of the study is to investigate the overall corporate objectives i.e. corporate strategy, the mechanism adopted in realising it, and how it positions itself relative to the business environment. The study found via a mono-method, online quantitative survey that although CPSFs adopt different corporate strategic objectives, their business strategies are in many ways similar. Findings also show that as firm size increases, strategists shift from a reactive state to defending their market share. This paper provides critical empirical evidence regarding the competitive strategies in SMEs, and the findings advance the discourse by practitioners on collaboration between CPSFs who are required to work together on construction projects, while adopting different competitive strategic choices.

Keywords: competitive strategy, service firms, corporate strategy, cross-case analysis

INTRODUCTION

The construction industry is a critical component of the world economy, particularly in terms of job creation and contribution to national output (McKinsey Global Institute, 2017). The direct contribution of the construction sector to the Irish economy stood at almost €21bn or 6.6% of GDP (Central statistics office, 2019). While this figure is still far from levels recorded during the peak in 2007, the

[1] d15125785@mydit.ie

Seriki, O and Murphy, R (2019) Competitive Strategies in Small and Medium Sized Enterprises (SME's): A Cross-Case Analysis of Irish Construction Professional Service Firms *In:* Gorse, C and Neilson, C J (Eds) *Proceedings of the 35th Annual ARCOM Conference,* 2-4 September 2019, Leeds, UK, Association of Researchers in Construction Management, 772-781.

construction industry in Ireland continues to play a critical driving role for economic growth. There are calls for fostering collaboration and improved dialogue between project teams amid increasing complexity in the industry (AECOM Ireland, 2019). The complex and disparate nature of the construction industry does not favour long-term organisational planning and the sector has been criticised as slow to change (Graham and Thomas, 2005). The Irish construction sector has also been criticised by authors such as Murphy (2013) for the lack of empirical research into the strategic management of professional service firms (PSFs), in particular as they comprise a significant portion of the construction industry. Research into the strategic management practices of these organisations is vital to plan for future cyclical fluctuations.

The changes experienced within the sector were unprecedented in severity and duration and have been explored in relation to contracting firms but thus far not relating to construction PSFs, particularly small and medium enterprises. The focus of existing research tends to focus on large firms e.g. Price (2003), Tansey *et al.,* (2017). Secondly, existing research has a tendency to focus on a single profession rather than providing a cross-professional analysis, which reflects the multidisciplinary nature of construction project teams. For example, Flemming (2011), focused on Irish architectural practices; Murphy (2013), focused on Irish quantity surveying practices, but neither compared across professions. Thus, a holistic study is warranted to explore PSFs across professions in the construction industry (architectural, engineering and surveying). Since construction PSFs comprise mainly of Architecture Engineer and Surveying (AES) firms, this paper examines strategy processes within all three professions, with a specific focus on SMEs.

The paper addresses three key objectives. First, it investigates competitive positioning and overall corporate objectives of AES firms in Ireland. Secondly, it identifies the mechanisms adopted in pursuit of competitive positions (i.e. business level strategies). Thirdly, the study benchmarks the strategic type of the strategist within individual practices against established typologies in the existing literature in a bid to understand the influence of the senior managers on strategic choices made. The specific characteristics identified within the study are competitive positioning scales relevant to PSFs and are adapted to inform strategists about the tasks to be considered in pursuit of competitive advantage.

LITERATURE REVIEW

The landscape within which PSFs currently operate within construction in Ireland is one characterised by a constant change, increasing complexity and competitive pressure. Strategy research has been concentrated on the manufacturing and product context with limited attention given to the services sector (Homburg *et al.,* 2002), particularly within construction. The services sector i.e. architectural, engineering and other construction technical services contributed a net value of €151m as at year end 2017 alone (CSO, 2019). For a sector with such significant contribution to national output, it is surprising that the analysis of strategic management in construction PSFs primarily emerged post 2010 (i.e. Flemming, 2011; Murphy, 2013). Since then, only a limited number of longitudinal studies involving strategy have been conducted, with no known study adopting a multidisciplinary approach to the topic, focusing instead on a single profession rather than across key stakeholders within construction. Due to the limited research on the subject, this paper addresses the perceptible gap by providing a multidisciplinary comparative analysis.

Strategic Management as a Body of Research

Porter (1980), a seminal author within strategy research defined the concept as '… a combination of the ends (goals) for which the firm is striving and the means (policies) by which it is seeking to get there.' This definition aligns with the objectives of this study and covers all three areas of focus, namely: Corporate strategy (goals), business strategy (means of getting there) and strategic type. Strategy research has enjoyed contributions from various related areas such as political science, economics, organisational sociology and cognitive psychology, and has developed a robust theoretical base across several research areas (Gongmin Bao, 2015). It has since evolved and expanded into a highly diverse field spanning business, public and private sector firms. One of the key areas of strategy evolution relates to competitiveness within turbulent business environments. Construction is one of such turbulent business environments as the sector is renowned for complexity, multiple stakeholders, uncertain nature of its projects, and dynamism of its outputs (Betts and Ofori, 1992).

Corporate level strategy

Corporate strategy relates to the method(s) by which a firm manages their entire business together (Grant, 1995). These high-level corporate objectives are concerned with what choices managers must make, particularly in relation to competition, selecting value creation activities and whether to enter, consolidate, or exit businesses for the maximization of long-term profitability. Three key types of corporate strategy include growth, stability, and renewal (Robbins and Coulter, 2012). A growth strategy is when a firm expands the number of markets served or services offered, while stability strategy is when a firm continues to do what it is currently doing. The third corporate strategy is renewal or downsizing, which occurs when due to challenges (whether financial, competitive or internal), the firm seeks to address declining performance. This last category is split into two called retrenchment and turnaround strategies. A fourth category is a combination of two strategies i.e. either expansion/maintenance or maintenance/downsizing in order to capture the full picture of the strategy process.

Murphy (2013) found the corporate strategy pursued by Irish QS firms to be broadly spread across all four options; however, the industry has significantly changed since the study was undertaken. The next level of strategy, which describes the business choices undertaken by firms to achieve the corporate strategy, is now explored in detail.

Business level strategy

Business level strategy relates to how a company competes to achieve the corporate strategy. Business strategy is grounded in the seminal work of Porter (1980; 1985), who espoused three generic strategies: Cost leadership, differentiation and focus. These strategies seek to outline the way an organisation positions itself in the marketplace to achieve the corporate goal and gain competitive advantage. Various positioning strategies can be used in different industry settings (Porter, 1980). Porter's business strategies appear to be the preferred mechanism for identifying the strategic options/choice pursued by construction firms, as several authors have utilised them when analysing Irish construction strategy (Flemming, 2011; Murphy, 2013; Tansey *et al.,* 2014). The focus strategy is sometimes extended to become "cost-focus" and "differentiation-focus"(Porter, 1980; 1985). Another variation is what Porter, terms as being “stuck in the middle”, which occurs when firms decide to adopt more than one

of the successful generic strategies in their business. Some authors have criticised Porter's work, particularly his notion of being ‘‘stuck in the middle,’ with claims that a combination of cost leadership and differentiation can also be a valid option (e.g., Miller and Dess, 1993). This criticism is taken into account in this study and the cost-differentiation option included as part of the business strategy options. A combination of generic strategies (hybrid strategies) may be ideal for achieving competitive advantage (Tansey *et al.,* 2014), in SMEs (Spanos *et al.,* 2004), and even during times of economic downturn (Wu *et al.,* 2007).

To a large extent the behaviour of strategists at senior level will have a significant impact on the strategic direction of an organisation, and how these decision-makers position their firm relative to the external environment will now be explored in detail.

Strategic type

Miles and Snow (1978) posit that a firm's positioning relative to strategy will have an impact on the formality of the process, and they named these approaches “strategic types”. They argue that although each firm may adopt different strategies based upon their unique characteristics, the behavioural patterns exhibited by the strategist will centre around four organisational types namely: Prospector, analyser, defender and reactor. These typologies help to explain how the strategist, and consequently the overall organisation interacts with the business environment i.e. their behaviour in response to environmental forces. Table 1 further explains the typologies:

Table 1: Miles and Snow (1978) strategic types

Strategic types	Description
Prospector	Seek to offer new services and enter new markets. These firms strive to provide innovative services into a market, and are quick to spot/react to opportunities
Defender	Tend to have a narrow market domain and are prone to create/maintain a niche with a limited range of services.
Reactor	Reactor firms do not have clearly articulated long-term goals or strategies, and consequently no uniform behaviour pattern.
Analyser	These firms seek stable markets and follows other competitors into new markets

Stewart *et al.,* (2000) highlight that individual firms within any of the four typologies display unique patterns in their decisions in response to changes in the business environment. Despite the wide adoption of these typologies to strategy analysis, very few criticisms exist to their use. Notable among these is the argument by Desarbo *et al.,* (2005) that businesses leverage their internal strengths (capabilities) and external (environment) circumstances, and these may not, in fact, be easily interpretable by the Miles and Snow (1978) categories. In a counter-argument, Murphy (2013) posits that typologies should only act as a point of reference for analysis rather than as prescriptive guidelines. Thus, these four typologies are adopted as guidelines in analysing how these construction organisations approach strategy and their interactions with their environment (i.e. the Irish construction sector).

Strategic Management in Construction

Studies into strategy in construction have spanned decades as several authors in construction such as Betts and Ofori (1992) have investigated the topic in the early 1990s. A key problem identified by Cheah and Chew (2005) is that several construction firms downplay corporate-level management, as they are often content to stay afloat one project at a time. This project-centrism makes it difficult to obtain information on strategy within individual firms, thus limiting academic inquiry. A large number of studies in construction focus on profession-specific studies and the

generalisability of such single-profession studies is problematic, as each profession within construction is unique. In Ireland, there has been an attempt by researchers to bridge the multidisciplinary gap, including Tansey *et al.,* (2017) that examined strategy in five large engineering and QS firms. However, the analysis does not take account of architectural practices and adopts a small sample size, making it difficult for the findings to be generalizable across the AES professions. In addition, these firms collaborate on a project level, yet they have very different strategic goals (at corporate or business level). Yet, there is no evidence to suggest that the strategies being employed within a particular profession are the same adopted across all PSFs in construction, hence the need for comparative analysis.

Unique nature of Professional Service Firms

One of the key characteristics that sets PSFs apart is their knowledge intensive nature, high level of client interaction and customised nature of service offerings (Lowendahl, 2000). Strategic management in PSFs is centred on professionals (people), and the body of knowledge in construction would benefit immensely from insights in CPSFs. Ling *et al.,* (2006) in their research into CPSFs stress the need for construction organisations to consider their strategy in order to ensure survival through economic cycles. For the purpose of this research, AES firms will be used as the unit of analysis. In general terms, 'CPSF' is used in reference to construction PSFs included under the Building Control Act 2007 (Irish Statute Book, 2016) and registered as Architectural, Surveying and Engineering firms in Ireland. In Ireland, professional bodies regulate the activities of AES firms. These bodies include the Royal Institute of the Architects of Ireland (RIAI); Association of Consulting Engineers Ireland (ACEI) and the Society of Chartered Surveyors Ireland (SCSI). Conducting strategy analysis within these organisations will help them understand their business as well as professional goals (Maister, 2012). The other distinguishing factor explored in this study is firm size and the impact on strategy.

Preoccupation with large firms

A key gap identified in this study is the predominant focus on large firms in strategic management research within construction (Lowstedt *et al.,* 2011; Oyewobi *et al.,* 2015; and Tansey *et al.,* 2017). The Irish Central Statistics Office (CSO) reports that SMEs accounted for 99.8% of total number of enterprises in 2016 and over 68% of all persons engaged (CSO, 2019). For the purposes of this research, small firms are classified as firms having between 1-10 employees while medium sized firms are firms having between 11-50 employees. This classification differs from the EU classification, as the firm size was adjusted to scale to fit the Irish construction industry context, consistent with the work of Murphy (2013). Given the majority of firms in the Irish construction sector are SME's, there is a need for a reorientation of research focus to these firms.

METHODOLOGY

This paper adopts a mono-method, deductive approach to data collection, analysis and interpretation. Bell (2005) posits there is no standard methodology that can be applied to all research problems, and the choice of methodology is based on the type of data readily available and the nature and scope of the topic at hand. The philosophical stance of this study is pragmatism, which allows a researcher to view a topic from either a constructivist or objectivist point-of-view (Saunders *et al.,* 2009). The research approach employed in the study is deductive in nature (Alvesson and Sköldberg, 2009), and the data collection instrument is a quantitative survey, which

allowed for a highly economical way of collecting large amounts of data to address the research questions/objectives (Saunders *et al.,* 2009). A rigid and well-justified sampling strategy was followed i.e. non-probability sampling, since the research population was already defined (member firms of the predefined professional bodies). Purposive sampling technique, where participants are chosen on the basis of personal judgement and established criteria was used (Miles and Huberman, 1994). In collaboration with the ACEI, RIAI and SCSI, firms registered on the professional body database were used thus defined the sample population.

The design of the questionnaire was based on established strategy metrics highlighted in the literature review i.e. corporate/business level strategy and strategic typologies. The survey was pilot tested amongst a number of CPSFs, and feedback from the pilot test was incorporated into a final refined survey which is potentially replicable in within PSFs in construction and other sectors. The survey was administered using an online survey instrument to a single key informant at senior manager level within member firms of the ACEI, RIAI and SCSI. The data from the study was not subjected to statistical analysis as the study is purely exploratory as opposed to explanatory i.e. to investigate what is there as opposed to investigating causality. Table 1 below presents the demographic data of the study.

Table 1: Profile of respondent firms

	Population	Responses	Res. Rate (%)	No. of SMEs	% SMEs
Architectural (ARCH)	510	116	22.75	112	96.6%
Engineering firms (ENG)	99	43	43.43	30	68.2%
Surveying firms (PQS)	236	66	27.69	60	90.9%

FINDINGS

Corporate Strategy of SME PSFs

Table 2 outlines the corporate strategy analysis of Irish SME PSFs. The table shows that majority of the respondent firms are expanding across the board except small sized PQS firms. No engineering practice within the population is undergoing downsizing, showing a robust outlook in the sector, similar to mid-sized PQS firms.

Table 2: Corporate level strategies of CPSFs

	ARCH	(%)	ENG	(%)	PQS	(%)
	Small	Medium	Small	Medium	Small	Medium
Consolidation	30.12	21.05	43.75	23.08	44.44	20.00
Expansion	55.42	57.89	50.00	76.92	31.48	60.00
Downsizing	7.23	5.26	0.00	0.00	11.11	0.00
Combination	7.23	15.79	6.25	0.00	12.96	20.00

As engineering firms move from small to medium, their corporate objectives become more defined i.e. they are either undergoing expansion or consolidation. More than 40% of small engineering and PQS firms are consolidating, meaning that their organisations protect and strengthen their position in their current markets with current service offerings (Johnson *et al.,* 2008). These firms seek to maintain their market share in existing markets; however, this does not necessarily mean that they are stagnating. It may mean that they are keeping the existing portfolio of clients and business size or reinforcing their market position within the growing construction sector.

One tenth of small PQS practices in the sample are downsizing and this may be connected to the concerns of worker shortages identified by Murphy (2018). The

report highlighted critical skills shortage within PQS practices, and this is an increasing concern within the profession. Medium sized architectural and PQS firms exhibit similarity in terms of corporate strategy except that medium sized PQS firms are not downsizing at all. Rather, their focus is primarily on expansion, which Deng and Yang (2015) posit may be due to confidence based on internal capabilities and strengths or externally driven market pressure.

Table 3: Business level strategies of CPSFs

	ARCH	(%)	ENG	(%)	PQS	(%)
	Small	Medium	Small	Medium	Small	Medium
Low-cost	3.61	5.26	0.00	0.00	14.81	20.00
Differentiation	55.42	42.11	18.75	23.80	48.15	80.00
Focus	16.87	10.53	12.50	7.69	5.56	0.00
Cost-focus	0.00	5.26	0.00	0.00	1.85	0.00
Diff.-Focus	22.89	31.58	68.75	69.23	24.07	0.00
Cost-Diff.	1.20	5.26	0.00	0.00	5.56	0.00
Stuck in the middle	0.00	0.00	0.00	0.00	0.00	0.00

Findings shown in table 3 highlight that engineering firms do not compete at all on a low-cost basis, followed by architectural firms who also do not seek cost-leadership with only about 5% of the sample size outlining that they compete on low-cost. In PQS firms however, one fifth of respondents seek to achieve cost-leadership. These firms tend to focus more on competitors rather than clients, and seek to outprice the competition (Frambach, et. al, 2003). Nearly half of the SME population in architecture firms select the differentiation business strategy, having similar characteristics with PQS firms, which has 48.15% of small firms confirmed. However, a surprising 80% of PQS practices are currently choosing the differentiation strategy. Oyewobi *et al.,* (2014) outlines that when construction organisations adopt differentiation strategies, it is in a bid to ensure survival in complex business environments. It is reasonable to assume that this may be the case in Ireland.

Notably, none of the SME firms across all professions are stuck-in-the-middle, which Johnson *et al.,* (2008) argue is a recipe for failure as such firms do not have a clearly defined means of achieving their business objectives. The findings within business level strategy shows marginal difference from the pattern observed in corporate-level strategy, with engineering firms still posing as an outlier and having unique strategic choices. While engineering and PQS firms predominantly tilt towards differentiation strategy as the preferred choice, engineering firms are less inclined so.

The data in table 4 shows similar patterns between architecture and PQS firms, particularly small firms. Prospector firms are innovative, creating new markets and enacting uncertain environments (Miles and Snow, 1978), however Irish SMEs show very limited prospector characteristics. The reactor typology is predominant across all professions within the sample, with these firms being late to change - often too late - and usually performing below the industry mean (Brunk, 2003).

Table 4: Miles and Snow Strategic typologies

	ARCH	(%)	ENG	(%)	PQS	(%)
	Small	Medium	Small	Medium	Small	Medium
Prospectors	7.41	21.05	12.50	0.00	12.96	20.00
Defenders	18.52	42.11	12.50	38.46	11.11	20.00
Analysers	33.33	10.53	6.25	15.38	35.19	0.00
Reactors	40.74	26.31	68.75	46.16	40.74	60.00

Only medium sized architectural firms are primarily defenders, who characteristically choose to focus on cost control, maintaining stability and process innovation (Parnell *et al.,* 2015). In addition, as firm size increases, firms move from being predominantly reactors to defenders. Becoming more defensive in their strategic typology would require concentrating on ongoing strategic challenges rather than potential markets (Parnell *et al.,* 2015). Cabrera *et al.,* (2008) also argued that defenders are often left with no option than to compete on a low-cost basis, however links between strategic type adopted and business strategy choice is not investigated in this study. Miles and Snow (1978) also suggested that organizations adopting clear generic strategies (i.e. prospectors, defenders, and analysers) typically outperform those without one (i.e. reactors), leaving room to investigate this further via a qualitative study, which will be conducted in phase II of this research.

CONCLUSION

This paper has investigated strategy processes in professional architecture, engineering and surveying firms within the Irish construction sector. These firms who are required to work together on projects have been well studied on project level but have not been studied on a strategic level. One of the significant findings to emerge from this study is that majority of PSFs within the SME category in Ireland are undergoing expansion and not seeking to downsize. This supports forecasts from the CSO of continuous growth in the sector. The study also found that engineering firms do not engage in any form of low-cost strategy, but rather heavily rely on differentiation-focus strategy. In addition, the preferred strategic choice of architecture and PQS firms is differentiation, consistent with theory about PSFs seeking differentiation. Notably, only small PQS firms compete considerably on a low-cost basis, possibly in a bid to gain market share. None of the SME firms across all professions are stuck-in-the-middle, which shows that these firms are clear about their business strategies. Lastly, this study has shown that there is a positive correlation between size and the strategic type i.e. as firm size increases, strategists shift from a reactive state to defending their market share (i.e. they move from being predominantly reactors to defenders). Although the literature suggests that, there are possible links between strategic typologies and business strategy, the opportunity to investigate this in the next phase of the research has been identified.

As firms within the industry are being encouraged to collaborate more, despite having different strategic goals, this paper has highlighted these differences and forms the basis for better understanding the uniqueness of individual PSFs going forward.

REFERENCES

AECOM Ireland (2019) *Taking the Long View, Ireland Annual Review 2019*, Available from https://ireland.aecom.com/ [Accessed 19/07/2019].

Alvesson, M and Sköldberg, K (2009) (Post-)positivism, social constructionism, critical realism: Three reference points in the philosophy of science, *Reflexive Methodology: New Vistas for Qualitative Research*, 15, 15-52.

Bell, J (2005) *Doing Your Research Project*. Buckingham: Open University Press.

Betts, M and Ofori, G（1992) Strategic planning for competitive advantage, *Construction, Management and Economics*, 10(**6**), 511-532.

Brunk, S E (2003) From theory to practice: Applying miles and snow's ideas to understand and improve firm performance, *Academy of Management Executive*, 17(**4**), 105-108.

Cabrera, Á, Cabrera, E F and Barajas, S (2008) The key role of organizational culture in a multi-system view of technology-driven change, *International Journal of Information Management*, 21(**3**), 178-199.

Central Statistics Office (2019) *Exports and Imports of Services by Component, Statistical Indicator and Year*. Available from https://www.cso.ie/px/pxeirestat/Statire/SelectVarVal/Define.asp?maintable=BPA03&PLanguage=0 [Accessed 19/07/2019] Ireland: Central Statistics Office.

Cheah, C and Chew, D A S (2005) Dynamics of strategic management in the Chinese construction industry, *Management Decision*, 43(**4**), 551-567.

Deng, P and Yang, M (2015) Cross-border mergers and acquisitions by emerging market firms: A comparative investigation, *International Business Review*, 24(**1**), 157-172.

DeSarbo, W S, Di Benedetto, C A, Song, M and Sinha, I (2005), Revisiting the miles and snow strategic framework: Uncovering interrelationships between strategic types, capabilities, environmental uncertainty and firm performance, *Strategic Management Journal*, 26, 47-74.

Flemming, K (2011) *Strategic Leadership of Architectural Firms in Ireland: the Role of Emotion, Management and Innovation*. Dublin City University. DCU Business School

Frambach, Ruud, T, Prabhu, J and Verhallen, T (2003) The influence of business strategy on new product activity, *International Journal of Research in Marketing*, 20(**4**), 377-397.

Gongmin Bao (2015) What theories are needed for strategic management? *Nankai Business Review International,* 6(**4**), 433-454.

Graham, B and Thomas, K (2005) An investigation into the development of knowledge management systems within the leading Irish construction companies. *In:* Khosrowshahi, F (Ed.), *Proceedings of the 21st Annual ARCOM Conference*, 7-9 September 2005, London, UK. Association of Researchers in Construction Management, Vol. 1, 499-508.

Grant R M (1995) *Contemporary Strategy Analysis, 2nd Edition*. Oxford: Basil Blackwell.

Løwendahl, B R (2007) *The Strategies and Management of Professional Service Firms*. Copenhagen: Copenhagen Business School Press

Löwstedt, M, Räisänen, C and Stenberg, A C and Stenberg, A-C (2011) How does change happen in a large construction company: Comparing objectified and lived versions of change. *In:* Egbu, C and Lou, E C W (Eds.), *Proceedings of the 27th Annual ARCOM Conference*, 5-7 September 2011, Bristol, UK. Association of Researchers in Construction Management, 84-94.

Homburg, C, Hoyer, W D and Fassnacht, M (2002) Service orientation of a retailer's business strategy: Dimensions, antecedents and performance outcomes, *Journal of Marketing*, 66(**4**), 86-101.

Irish Statute Book (2016) *Irish Statute Book*. Available from http://www.irishstatutebook.ie/eli/2016/si [Accessed 20/03/2019].

Linesight (2019) *Linesight Knowledge Center, Value of Construction Output 2007-2018*, Available from https://www.linesight.com/knowledge/2018/ireland/value-of-construction-output-2007-2018 [Accessed 20/03/2019].

McKinsey Global Institute (MGI) (2017) Reinventing Construction: A Route to Higher Productivity. Available from https://www.mckinsey.com/industries/capital-projects-and-infrastructure/our-insights/reinventing-construction-through-a-productivity-revolution [Accessed 19/07/2019].

Maister, D H (2012) *Managing the Professional Service Firm*. New York: Simon and Schuster, Inc

Miles, R E and Snow, C (1978) *Organisational Strategy Structure and Process, Stanford Business Classics*. California, Stanford Business Books.

Miller, A and Dess, G (1993) Assessing Porter's (1980) model in terms of its generalizability, accuracy and simplicity, *Journal of Management Studies*, 30(**4**), 553-585.

Murphy, R (2013) Strategic planning in construction professional service firms: A study of Irish QS practices, *Construction Management and Economics*, 31(**2**), 151-166.

Murphy, R (2018) *Employment Opportunities and Future Skills Requirements for Surveying Professionals*. Report SCSL, 1-85.

Oyewobi, L O, Windapo A O and James R O B *(*2015) An empirical analysis of construction organisations' competitive strategies and performance, *Built Environment Project and Asset Management*, 5(**4**), 417-431.

Parnell, J A, Long, Z and Lester, D (2015) Competitive strategy, capabilities and uncertainty in small and medium sized enterprises (SMEs) in China and the United States, *Management Decision*, 53(**2**), 402-431.

Porter, M E (1980) *Competitive Strategy: Techniques for Analysing Industries and Competitors*. New York: Free Press, Collier Macmillan.

Porter, M E (1985) *Competitive Advantage: Creating and Sustaining Superior Performance*. New York: Free Press.

Price, A D F (2003) The strategy process within large construction organisations, *Engineering, Construction and Architectural Management*, 10(**4**), 283-296.

Robbins, S P and Coulter, M (2012) *Management*. London: Pearson.

Saunders, M, Lewis, P and Thornhill, A (2009) *Research Methods for Business Students*. London: Prentice Hall.

Stewart, J P (2000) *Strategic IT Maturity of Construction Companies*. PhD Thesis, Department of Building and Construction Economics, Faculty of the Constructed Environment, Royal Melbourne Institute of Technology.

Spanos, Y, Zaralis, G and Lioukas, S (2004) Strategy and industry effects on profitability: Evidence from Greece, *Strategic Management Journal*, 25(**2**), 139-165.

Tansey, P, Spillane, J P and Meng, X (2014) Linking response strategies adopted by construction firms during the 2007 economic recession to Porter's generic strategies, *Construction Management and Economics*, 32(**7-8**), 705-724.

Tansey, P, Spillane, J P and Brooks, T (2017) Creating opportunities in the face of an environmental jolt: Exploring turnaround strategizing practices within large Irish construction contractors, *Construction Management and Economics*, 36(**4**), 217-241.

Wu, H-L, Lin, B-W and Chen, C-J (2007) Contingency view on technological differentiation and firm performance: Evidence in an economic downturn, *R&D Management*, 37(**1**), 75-88.

INTERNATIONAL MARKET SELECTION OF INFRASTRUCTURE CONSTRUCTION INVESTMENT ALONG 'ONE BELT AND ONE ROAD': THE CASE OF ASEAN COUNTRIES

Yi-Hsin Lin[1] and Ziheng Su[2]

[1] *Department of Construction and Real Estate, School of Civil Engineering, Southeast University, No. 2, Southeast University Rd., Nanjing, Jiangsu, 211189, China.*

[2] *Department of Informatics, Faculty of Natural and Mathematical Sciences, King's College London, strand, London, WC2R 2LS, UK*

Under the active support of the national policy "One Belt and One Road" (OBOR) Initiative, Chinese construction contractors are trying to seize this historic opportunity to accelerate strategic globalization, of which the first step for them is selecting suitable markets that are important to win the fierce market competition brought by the process of internalization. This paper develops a comprehensive international market selection (IMS) approach for infrastructure construction investment along OBOR using the objective information and mathematical algorithm. The objective information consists of 13 factors related to national risk and project reward and builds a market evaluation system. The mathematical algorithm includes Technique for Order Preference by Similarity to an Ideal Solution (TOPSIS) based on information entropy theory and cluster analysis with SPSS. Then, the Association of Southeast Asian Nations (ASEAN) countries are taken as research samples to verify the feasibility of the approach. The results show that Brunei is the high-risk and high-reward market; Indonesia and Philippines are low-risk and low-reward markets; Laos, Cambodia and Myanmar are high-risk and low-reward markets; while Singapore, Thailand, Malaysia, and Vietnam are low-risk and high-reward markets. The results may not only help Chinese contractors select better candidate markets to enhance their sustainability in the international market, but also have great theoretical and practical significance.

Keywords: ASEAN, OBOR, information entropy theory, TOPSIS

INTRODUCTION

International expansion is becoming more imperative in today's marketplace (Ozturk *et al.,* 2015), which also happens in the field of infrastructure construction. With the support of the multinational cooperation framework of "One Belt and One Road" (OBOR) Initiative whose main goal is creating an all directional, multi-level, and interconnected infrastructure network (Zhao *et al.,* 2016), the needs for acceleration of infrastructure investment and infrastructure upgrading in 66 related countries provide various market opportunities (Feng 2016). Even though choosing a suitable market could give contractors a competitive advantage in the fierce market competition (Kakol and Twarowska 2013), the international market selection (IMS) is not a

[1] yihsinlin@seu.edu.cn

Lin, Y-H and Su, Z (2019) International Market Selection of Infrastructure Construction Investment Along 'One Belt and One Road': The Case of ASEAN Countries *In:* Gorse, C and Neilson, C J (Eds) *Proceedings of the 35th Annual ARCOM Conference,* 2-4 September 2019, Leeds, UK, Association of Researchers in Construction Management, 782-790.

straightforward task (Magnani *et al.,* 2018). IMS is one of the most complicated and time-consuming problems, due to the large number of alternatives, conflicting objectives, and variety of factors (Aghdaie *et al.,* 2013). This implies that the decision-making process must consider several criteria, which makes IMS a multicriteria decision-making problem, whose objective is to find an optimal alternative among candidate (Dat *et al.,* 2015). China-ASEAN (The Association of Southeast Asian Nations) Free Trade Area is one of the greatest World Federation of Free Trade Zones. Therefore, how Chinese contractors select better candidate country to enter is crucial for achieving project success in ASEAN.

The research aims to develop a comprehensive IMS approach for infrastructure construction investment along OBOR using the objective information and mathematical algorithm. In this paper, 13 factors are selected from two aspects of national risk and project reward based on theories of market selection, and a comprehensive international market evaluation system for infrastructure is established (Lee *et al.,* 2017). By quantifying the influence factors of various objective indexes, the ideal point method based on information entropy theory is used to process the data (Fan and Wang 1998). Finally, two corresponding scores are obtained for each country in ASEAN. The sample scores are clustered by SPSS, and the target markets are classified into four categories: High risk and high reward, high risk and low reward, low risk and high reward and low risk reward (Lee *et al.,* 2017).

Theoretical Frame

The literature varies widely on how to select a suitable international market and the debate focuses on influence factors and market evaluation methods. In the aspect of influence factors, Shi (2012) studied IMS from 3 aspects based on the institutional theory: Institutional distance, cultural distance and trade frequency. Ghemawat (2001) believed four elements of CAGE distance theory (Cultural, Administrative, Geographic and Economic distances) still have influence on market choice. Zhao *et al.,* (2016) hold that market situation and development are key factors and classified 66 OBOR countries according these. At the same time, how to evaluate target markets is also a key problem. Cano (2017) used fuzzy logic for the uncertainty of the variables in the market evaluation. Through Monte Carlo simulation, the market evaluation model measures the stability of international markets for exporting when criteria are fuzzy. Through a multiple case study methodology, Maganani (2018) conducted a comparative analysis and studied the revealing the role of firm-specific strategic objectives as determinants of foreign market.

The study introduces a quantitative approach for diagnosing the multi-dimensional aspects of target countries using both country-level and project-level variables. That is, to evaluate the target from each single point of view, and then integrate the information of each evaluation index to get a comprehensive index that can be judged as a whole and to compare horizontally or vertically on this basis. Through collecting and sorting out the relevant theories of market selection, including Eclectic Theory of International Production (ETIP) (Dunning 2000), Theory of National Overall Attractiveness (TNOA) (Hill 2002) and New Institutionalism Theory (NIT) (North 1981), 13 specific evaluation indexes are selected as follows:

Trade link (C_{11}): Frequent trade links can reduce the risk of uncertainty and encourage contractors to form economies of scale, save costs and increase profit margins. Correspondingly, the larger the total import and export trade volume of two countries,

the closer the trade relationship between the two countries and the more frequent the economic ties (He and Zhang 2009).

Geographical distance (C_{12}): The increase of geographical distance will obviously increase transport costs and affect the cost of intangible goods and services trade. The geographical distance takes into account the regional area of two countries, whether they are landlocked countries, population and other factors, which can better explain the geographical distance between the two countries.

Institutional distance (C_{13}): Enterprises entering the international market need to rely on the legal system of the host country and the way of acting by the state organs to maintain business activities, while the differences in the level of institutional development increase obstacles and risks.

Government governance (C_{14}): The level of political governance in developing markets may be a major risk issue. Political stability means that political risks are small, which can reduce the risks and uncertainties faced by contractors. The political stability of the host country will determine the success of foreign investors in the country (Minifie and West 1998).

Judicial justice (C_{15}): As a long-term and complex project, infrastructure construction may involve legal disputes with local suppliers or owners (Kerur and Marshall 2012). Fair judicial procedures can protect the interests of contractors, but also make contradictions and disputes can be reasonably resolved.

Market opportunity (C_{21}): When choosing the market, international engineering enterprises tend to enter the high-growth market (Agarwal and Ramaswami 1992). On the contrary, in the case of low market potential, companies are unlikely to undertake large resource commitments (Brouthers 2013).

Market competition (C_{22}): Strong competition will reduce the level of profits and the average growth rate of sales for specific companies (Harrigan 2010). Once they fail in the competition, they will face huge sunk costs (Jia *et al.,* 2016). Therefore, enterprises are more inclined to enter the less competitive market.

Access to credit (C_{23}): The biggest human risk that contractors may face in the performance of engineering contracts is the breakage of project capital chain. It is very important for contractors to obtain stable and credible sources of loans (Kerur and Marshall 2012). This index analyses two issues: The strength of credit reporting system and the effectiveness of guarantee and bankruptcy law in promoting lending.

Enforcement of contracts (C_{24}): Effective execution of contracts is an important guarantee to ensure that the project is completed on time and to obtain expected profits. The index measures the time and cost of a local primary court in resolving a commercial dispute, as well as the quality of judicial proceedings. Judicial procedural quality indicators measure whether each economy has taken a series of good initiatives to improve the quality and efficiency of the court system.

Protection of minority investment (C_{25}): Protecting minority investment refers to protecting Contractors' rights in overseas project construction and measuring the full protection of minority investors when conflicts of interest occur. This indicator measures the protection of minority shareholders' rights when project investment partners abuse their finances in order to obtain private interests, and measures to reduce the risk of shareholders' interest impairment, including equity, governance and corporate transparency requirements.

Registered property (C_{26}): Based on a standardized case in which an entrepreneur wants to buy a registered land and building without ownership disputes, the registered property index measures the necessary procedures, time and cost for the entrepreneur to register the property.

Taxes (C_{27}): When evaluating the selected scheme, the tax consequences of local tax system and tax jurisdiction should be considered. This indicator records the taxes and mandatory payments that a medium-sized enterprise must pay or withhold in a year, the data show which countries have more efficient post-tax procedures and why the overall cost of tax compliance varies among economies.

Processing construction permits (C_{28}): This indicator records the procedures, time and cost of building a warehouse, including obtaining the necessary permits and approvals, submitting the required notifications, applying for and accepting all necessary inspections and obtaining public facilities. In addition, the construction permit index also inspects the construction quality control index, measures the quality of building laws and regulations, the strength of quality control and safety system, responsibility and insurance system, and the requirements for professional certification.

These factors consist a market evaluation system which contains 1 final "target A", 2 "B level index" and 13 "C level index". The national risk factor "B_1" includes 5 indexes and project reward "B_2" contains 8 indexes. Professional data are selected from the annual reports of professional institutions, and each index is processed quantitatively. Since the score of the upper level index is obtained through the treatment of the score of the lower level index, only the "C level index" needs to be quantified. The specific structure and content of the evaluation system are shown in Table 1.

Table 1: Structure and content of the market evaluation system

Target A	Factor B	Index C	Theory	Data Resource	Data Duration	Measurement/Scale
A	B_1	C_{11}	TNOA	China Statistical Yearbook	2014-2018	Total import and export/ million US dollars
		C_{12}	ETIP	CEPLL Database	2014-2018	Geographical Distance/km
		C_{13}	ETIP	World Governance Indicators	2014-2018	Degree of Economic Freedom/score
		C_{14}	TNOA	World Integrity Index	2014-2018	Integrity Index/ranking
		C_{15}	TNOA	World Justice Project Rule of Law Index Report	2014-2018	Rule of Law Index/score
	B_2	C_{21}	TNOA	OBOR National Infrastructure Development Index Report	2014-2018	Infrastructure Development Index/score
		C_{22}	TNOA	Engineering News Records	2014-2018	Number of Overseas Contractors/numbers
		C_{23}	NIT	World Business Index Report	2014-2018	Business index/Ranking
		C_{24}	NIT	World Business Index Report	2014-2018	Business index/Ranking
		C_{25}	NIT	World Business Index Report	2014-2018	Business index/Ranking
		C_{26}	NIT	World Business Index Report	2014-2018	Business index/ranking
		C_{27}	NIT	World Business Index Report	2014-2018	Business index/ranking
		C_{28}	NIT	World Business Index Report	2014-2018	Business index/ranking

RESEARCH METHODOLOGY

The counting and calculating process in this paper includes the following steps:

Step 1: Normalization. In the multi-index evaluation system, the nature of each index varies greatly. There are no similar criteria among the indexes, and the unit dimension is not consistent. The role of data standardization is to eliminate dimensional differences and minimize the impact of extreme values (Zhao *et al.,* 2016). Among the various methods of data standardization, the normalization method is relatively common and typical. It converts each value into the proportion and maps data processing to "[0,1]" in the whole sequence.

Step 2: Entropy of information weighting method. The index weight reflects the relative importance of each index and the coordination degree of the whole index system. On the basis of the established index system, the weighted summation method is often used to obtain the evaluation value (Fan 1998). In information theory, Shannon (1948) quoted the concept of entropy in physics and pointed out that any information has its own information entropy, which is an objective value that can be calculated by formula. Comparing with the weight of each index given by expert survey, it is more objective. Entropy "e" is a measure of the degree of uncertainty of the system (Liu and Zhang 2007). When the system is in "n" different states and the probability of occurrence of each state is "p_i", the system's entropy is:

$$e_j = -\frac{1}{\ln(n)} \sum_{i=1}^{n} p_i \ln p_i \ (0 \leq e_j \leq 1)$$

According to the formula of entropy, the definition of entropy weight is as follows:

$$\omega_j = \frac{1 - e_j}{\sum_{j=1}^{n}(1 - e_j)}$$

When the entropy of the system is small and the weight of the entropy is large, it shows that the system contains more information to help decision-making than other systems.

Step 3: Technique for Order Preference by Similarity to an Ideal Solution. Technology for Order Preference by Similarity to an Ideal Solution model (TOPSIS) is an effective method for multi-objective decision-making and improves the accuracy and operability (Hwang and Yoon 1981). Firstly, the data standardization is used to unify the quantified index values, and the ideal solution "C_1^+"and the negative ideal solution "C_1^-"are selected according to the principle of "Take the biggest in the big and the smallest in the small."

$$C^+ = \{(\max C_i \mid i \in J1), (\min C_i \mid i \in J2) \mid i = 1, 2, 3, 4, \cdots m\};$$

$$C^- = \{(\min C_i \mid i \in J1), (\max C_i \mid i \in J2) \mid i = 1, 2, 3, 4, \cdots m\}$$

The distance between each corresponding target and the ideal target is calculated by Minkowski distance or Euclidean geometric distance. In theory, the closer the distance is, the better the evaluation is. Finally, a ranking of advantages and disadvantages is obtained. The distance from each solution to a positive ideal solution is"S_J^+"; The distance from each solution to a negative ideal solution is "S_J^-"; The closeness of each corresponding index to the ideal solution is"B". The greater the degree of closeness, the more ideal. By sorting the degree of closeness in B set according to size, the sorting can be obtained.

$$S_J^+ = \sqrt{\sum_{i=1}^{m}(C_i - C^+)^2}, \ j = 1,2,3,\cdots,m.$$

$$S_J^- = \sqrt{\sum_{i=1}^{m}(C_i - C^-)^2}, \ j = 1,2,3,\cdots,m.$$

$$B_i = \frac{S_J^-}{S_J^+ + S_J^-} \ (0 \leq B_i \leq 1)$$

Step 4: Cluster analysis. It describes the characteristics of the original object by clustering method, analyses the similarity within the group and proceeds to classify. As the main purpose of data mining in practical application, clustering can provide multi-cluster data with different characteristics for the subsequent analysis process, which facilitates the subsequent analysis of specific characteristics and the decision of processing methods. At the same time, clustering analysis is also a necessary precondition for classification and qualitative induction in practical application. This study uses SPSS to do cluster analysis by taking K-means clustering.

RESULTS AND DISCUSSION

Taking ten ASEAN countries as samples, including Brunei (BN), Indonesia (ID), Kampuchea (KH), Laos (LA), Malaysia (MY), Burma (MM), Philippines (PH), Singapore (SG), Thailand (TH) and Vietnam (VN), this research method is applied to analyse IMS. According to the data sources shown in Table 1, the initial data are sorted out and standardized, and the weight of each index is calculated by entropy of information weighting method. The weights are combined with the standardized data to get the specification values. Table 2 below shows the data panels for weights and specification values

Table 2: Weights and specification values

Index C	ω_j	BN	ID	KH	LA	MY	MM	PH	SG	TH	VN
C_{11}	0.6037	0.0020	0.0783	0.0055	0.0038	0.1282	0.0204	0.0573	0.0999	0.0964	0.1121
C_{12}	0.1630	0.0149	0.0200	0.0128	0.0106	0.0167	0.0383	0.0109	0.0172	0.0126	0.0089
C_{13}	0.0259	0.0029	0.0025	0.0024	0.0021	0.0030	0.0020	0.0026	0.0037	0.0027	0.0022
C_{14}	0.1444	0.0212	0.0127	0.0074	0.0096	0.0175	0.0089	0.0126	0.0298	0.0131	0.0115
C_{15}	0.0630	0.0076	0.0066	0.0041	0.0037	0.0069	0.0053	0.0060	0.0102	0.0064	0.0064
C_{21}	0.0099	0.0008	0.0015	0.0009	0.0009	0.0010	0.0008	0.0009	0.0011	0.0009	0.0011
C_{22}	0.0606	0.0014	0.0092	0.0041	0.0038	0.0096	0.0042	0.0063	0.0076	0.0072	0.0072
C_{23}	0.1761	0.0132	0.0298	0.0493	0.0110	0.0030	0.0201	0.0278	0.0044	0.0119	0.0055
C_{24}	0.2352	0.0008	0.0218	0.0079	0.0305	0.0079	0.0702	0.0563	0.0115	0.0167	0.0115
C_{25}	0.1465	0.0093	0.0220	0.0272	0.0147	0.0067	0.0285	0.0226	0.0003	0.0052	0.0100
C_{26}	0.2338	0.0117	0.0126	0.0317	0.0505	0.0012	0.0537	0.0428	0.0012	0.0047	0.0238
C_{27}	0.0690	0.0108	0.0084	0.0098	0.0052	0.0033	0.0106	0.0090	0.0015	0.0054	0.0050
C_{28}	0.0690	0.0074	0.0081	0.0097	0.0111	0.0052	0.0089	0.0075	0.0005	0.0048	0.0061

The closeness of national risk and project reward to the ideal solution is as follows:

{0.1782, 0.5933, 0.1708, 0.1806, 0.8960, 0.1407, 0.4590, 0.7773, 0.7298, 0.8223}

{0.8150, 0.6038, 0.5117, 0.4854, 0.8765, 0.2408, 0.2707, 0.8850, 0.8041, 0.7424}

Each data is divided into two categories by cluster analysis using SPSS and the evaluation results are shown in Table 3.

Table 3: Evaluation results

	High Reward	Low Reward
High Risk	Brunei	Laos, Cambodia, Myanmar
Low Risk	Singapore, Thailand, Malaysia, Vietnam	Indonesia, Philippines

Compared with other Southeast Asian countries, Singapore, Thailand, Malaysia and Vietnam have better economic conditions, solid foundations, good economic prospects and large room for growth. However, they do not invest enough in infrastructure. Some of the infrastructure is old and even backward, which to some extent restricts the further development of the economy. Therefore, these markets have good prospects, and countries with large market space have the most obvious demand for infrastructure improvement. Brunei is a small country with a small volume of trade with China, and its relations with other countries do not have a great advantage. Moreover, the domestic infrastructure construction is mature, the market demand is small, and the entry risk of enterprises is high. However, once social and economic stability, complete system entered, there will be considerable project rewards. Indonesia and the Philippines have large economic aggregates, and both countries attach importance to infrastructure construction with rapid development. However, due to the long construction cycle and the large national development base, there is an urgent need to constantly update infrastructure, so there are still many construction opportunities. In addition, the two countries have close ties with China, frequent commercial exchanges, and the contractors are familiar with the economic and social conditions of the market, with relatively small risks. By comparison, Laos, Cambodia, Myanmar are the most backward in economic development. Owing to economic and social factors, most of these countries invest less in infrastructure and have lower opportunities and rewards. In addition, the government's inadequate governance and the problems of the social and economic system pose greater risks.

In summary, this approach can be applied successfully and the degree that the result accords with the realistic condition is high. Each of the four types of market has its own characteristics. Chinese international engineering contracting enterprises should screen market opportunities according to the actual situation.

CONCLUSIONS

In order to explore what factors, affect the decision making of Chinese contractors in infrastructure construction market selection along OBOR, this study establishes an objective multi-index IMS approach, uses the ten countries as an example for application and analysis. The results show that Brunei is the high-risk and high-reward market; Indonesia and Philippines are low-risk and low-reward markets; Laos, Cambodia and Myanmar are high-risk and low-reward markets; while Singapore, Thailand, Malaysia and Vietnam are low-risk and high-reward markets. The results may not only help Chinese contractors select better candidate markets to enhance their sustainability in the international market, but also have great theoretical and practical significance.

ACKNOWLEDGEMENTS

This work was supported by the National Natural Science Foundation of China (Grant Number: 71573037) and the Priority Academic Program Development of Jiangsu Higher Education Institutions in China (Grant Number: 1105007002).

REFERENCES

Agarwal, S and Ramaswami, S N (1992) Choice of foreign market entry mode: Impact of ownership, location and internalization factors, *Journal of International Business Studies*, 23(**1**), 1-27.

Aghdaie, M H, Zolfani, S H and Zavadskas, E K (2013) Market segment evaluation and selection based on application of fuzzy AHP and COPRAS-G methods, *Journal of Business Economics and Managemen*t, 14(**1**).

Brouthers, K D (2013) A Retrospective on: Institutional, cultural and transaction cost influences on entry mode choice and performance, *International Business Study*, 44(**1**), 14-22.

Cano, J, Campo, E and Gomez-Montoya R (2017) International Market selection using fuzzy weighing and Monte Carlo simulation, *Polish Journal of Management Studies*, 16(**2**), 40-50.

Dat, L Q, Phuong, T T, Kao, H P, Chou, S Y and Nghia, P (2015) A new integrated fuzzy QFD approach for market segments evaluation and selection, *Applied Mathematical Modelling*, 39(**13**), 3653-3665.

Dunning, J H (2000) The eclectic paradigm as an envelope for economic and business theories of MNE activity, *International Business Review*, 9(**2**) 163-190.

Fan, R and Wang, Z W (1998) A method of entropy weighting ideal point and its application in investment decision, *Journal of Wuhan Hydraulic and Electric University*, 31(**6**), 213-233.

Feng, B (2016) *One Belt and One Road: The Chinese Logic for Global Development*. Beijing: China Democratic and Legal Publishing House.

Ghemawat, P (2001) Distance still matters, *Harvard Business Review*, 79(**8**) 137-147.

Harrigan, K R (2010) Joint ventures and competitive strategy, *Strategic Management Journal*, 9(**2**), 141-158.

Hwang, C L and Yoon, K (1981) *Multiple Attribute Decision Making: Methods and Applications*. New York: Springer-Verlag.

He, B F and Zhang, X (2009) An exploration on the location selection model of Chinese enterprises' foreign direct investment, *Finance and Trade Economics*, 9(**2**), 96-101.

Hill, C W L (2002) *Global Business Today*. Boston: McGraw-Hill Irwin.

Jia, R Y, Li, Q M and Deng, X P (2016) Entry mode taxonomy and choice of Chinese international construction companies, *Management in Engineering*, 33(**3**) 46-58.

Kakol, M and Twarowska, K (2013) International business strategy reasons and forms of expansion into foreign market management, *Knowledge and Learning International Conference 2013*, 19-21 June, Zadar, Croatia.

Kerur, S and Marshall, W (2012) Identifying and managing risk in international construction projects, *International Review of Law*, 2012(**1**), 8-8.

Lee, K W, Jung, W Y and Han, S H (2017) Country selection model for sustainable construction businesses using hybrid of objective and subjective information, *Sustainability*, 9(**1**), 21-39.

Liu, J E and Zhang, H L (2007) Target market selection based on entropy weight ideal point method: China, *Management Informalization*, 10(**7**), 45-46.

Magnani, G, Zucchella, A and Floriani, D E (2018) The logic behind foreign market selection: Objective distance dimensions vs strategic objectives and psychic distance, *International Business Review*, 27(**1**), 1-20.

Minifie J R and West, V A (1998) Small Business international market selection model, *International Journal of Production Economics*, s56-57(**10**), 451-462.

North, D C (1981) *Structure and Change in Economic History*. New York: Norton.

Ozturk, A and Cavusgil, S T (2015) Delineating foreign market potential: A tool for international market selection, *Thunderbird International Business Review*, 57(**2**), 119-141.

Shannon, C E (1948) A mathematical theory of communication, *The Bell System Technical Journal*, 27(**3**), 379-504.

Shi, N Y (2012) Host Country selection of multinational corporations based on institutional theory, *Technology and Industry*, 12(**08**), 110-114.

Zhao, Z Y, Li, X C and Yao, M M (2016) Research on the infrastructure situation and market opportunities of the countries along the Belt and Road, *Construction Economy*, 37(**7**), 5-10.

THE STRATEGY PROCESS OF IRISH QUANTITY SURVEYING FIRMS OPERATING WITHIN A TURBULENT BUSINESS ENVIRONMENT

Michael Adesi[1], Róisín Murphy and Dermot Kehily

School of Surveying and Construction Management, College of Engineering and Built Environment, Technological University Dublin, Bolton Street, Dublin 1, Dublin, Ireland

Rapid technological changes and market fluctuations create a turbulent business environment that poses significant challenges to the strategy process of Quantity Surveying (QS) firms. A turbulent environment refers to the existence of high levels of uncertainty, unpredictability, volatile demand and changing growth conditions within an industry. The strategy process is complex and becomes more problematic in the face of a turbulent business environment. To date, studies focusing on QS practices seldom investigate the impact of a rapidly changing environment on the strategy process within these firms. This study aims to address this gap by investigating the impact of environmental turbulence on the strategy process and strategic choices made within Irish QS firms. This paper presents findings from the first of a two-phase data collection process, which adopts a quantitative approach based on data collected from a survey of senior management in Irish QS firms. The paper provides insight into the characteristics of the strategy process of QS practices operating in a turbulent business environment and outlines strategic choices made at the top management level of these practices. The paper contributes by identifying the impact of turbulent business environment on the strategy process of QS practices.

Keywords: strategic, planning, process, turbulent, environment, quantity surveying

INTRODUCTION

The construction industry is complex and highly changeable due to discontinuous demand, market uncertainty, supply chain complexity and the heterogeneous nature of the output. In Ireland, the construction industry has undergone significant change over the last number of years however, while there is considerable evidence pertaining to the effect of economic fluctuations on the construction industry (Tansey *et al.,* 2014), less emphasis has been placed on the impact of economic turmoil on the strategic decision-making process and strategic choices of QS firms. Environmental turbulence refers to increasing volatility, uncertainty, and instability in the business environment of organisations (Yasir *et al.,* 2017, 1150; Wong, 2014), the drivers of which include technological instability; and market fluctuations (Day and Schoemaker, 2016). Market fluctuations have also given rise to skills shortages (Murphy, 2018), which affect the choices available to QS practices.

The strategy process is a sequence of events and changes at the corporate and business levels that lead to critical outcomes in organisations (Huy and Guo, 2017).The

[1] d15126552@mydit.ie

Adesi, M, Murphy, R and Kehily, D (2019) The Strategy Process of Irish Quantity Surveying Firms Operating Within a Turbulent Business Environment *In:* Gorse, C and Neilson, C J (Eds) *Proceedings of the 35th Annual ARCOM Conference,* 2-4 September 2019, Leeds, UK, Association of Researchers in Construction Management, 791-799.

strategy process of QS practices operating in unstable business environments requires strategic choices at both the corporate and business level to operate effectively in a disruptive setting.. Corporate level choices are the options available to the chief executive officer and the board of directors while business level choices refer to the decisions of senior managers or senior executives based on the decisions of the top management (Castañer and Yu, 2017). Despite the fact that studies by Tansy *et al.,* (2014) focus on the response strategies of Irish contracting firms, investigations into the strategy process of QS practices operating in complex and unstable conditions are scarce.

LITERATURE REVIEW

The construction industry is significant to the socio-economic development in Ireland by contributing to the various sectors of the Irish economy. Despite the significant contribution of the Irish construction industry, the financial crisis has negatively affected its performance over the last ten years due to the recent prolonged economic recession (Nolan and Voitchovsky, 2015). QS practices, which are critical to the performance of the Irish construction industry are also facing the challenges created by the economic instability. QS practices are professional service firms engaged by clients to undertake cost management roles during construction project delivery (Lu *et al.,* 2019). Cost management in the construction industry comprises cost-related activities during project delivery, right from inception through successful completion and user occupancy (Ashworth, 2010). The traditional roles of QS practices include preliminary cost estimate, design-stage cost plan, tendering, cost control and preparation of variations and final account (Towey, 2012). Apart from the traditional cost estimating and cost planning functions, the roles of QS practices in construction project delivery have evolved into new responsibilities such as life cycle costing, mediation, adjudication or arbitration, value engineering, risk analysis, insolvency services, programme and project management and facilities management (Ashworth *et al.,* 2013). Both the traditional functions and emerging roles of QS practices have been affected by turbulent business environment discussed in the section below.

Turbulent Environment

A turbulent environment refers to the existence of high levels of uncertainty, unpredictability, demand volatility, and changing growth conditions within an industry. The strategy process is complex and becomes more challenging due to uncertainties posed by the disruptive business environment. The challenges of the disruptive business setting may be addressed by increasing knowledge of both top and middle-level managers on strategy process and alertness (Yasir et al.,2017). Alertness is the ability of business organisations to identify new economic opportunities that do not have prior recognition by other economic actors (Stolyarov II, 2005). Wong (2014) investigates the impact of environmental turbulence on entrepreneurial orientation and found that a turbulent business environment has a significant influence on entrepreneurial innovativeness. Entrepreneurial innovativeness in this paper refers to the ability of business leaders to adopt new methods, ideas, and strategies for organisational management and operation in order to develop new products or improve existing products or service (Khandwalla, 1987). The findings of Yasir *et al.,* (2017) and Wong (2014) specifically focus on entrepreneurs in the manufacturing sector, thus, this research focuses on QS practices whom must pay attention to the instability in their business setting.

Dess and Beard (1984) classify disruptive business settings as 'munificence'; 'complex'; and 'dynamic'. Environmental munificence refers to conditions of growth in organisations due to the availability of economic resources (Boyne and Meier, 2009). Environmental complexity refers to external circumstances that impose a burden on the organisation (Miller and Page, 2007). Furthermore, studies by Andrews *et al.,* (2005), Fernandez (2005), and Heinrich and Fournier (2004) establish that complexity hurts the performance of organisations. Dynamism refers to the unpredictability or the rate of change and innovation in an industry as well as the unpredictability of its customers' actions (Li and Liu, 2014). Thus, unpredictability creates a challenging business environment for firms with adverse consequences on their strategy formation and overall performance, which require an understanding of the strategy process in a disruptive business environment and its impacts on strategic choices in QS practices.

Scholarly investigations on the turbulent environment of organisations delve into both internal and external environmental conditions. The internal conditions include organisational culture, the type of management, and organisational structure that affect the functioning of the firm. External conditions involve economic, political, social and technological factors that arise from outside the organisations but have a significant impact on their operation and management. However, this warrants further research due to increasing disruptive conditions within and outside the business settings (McKelvie *et al.,* 2018; Vecchiato, 2015), it is crucial to delve into QS practices and turbulent environment below.

QS Practices Operating in Turbulent Environment

QS practices face several challenges in their service delivery to clients in the construction industry. The challenges of QS practices include fragmented processes in the construction industry, estimation of sophisticated design, tedious work, time pressure, and an image problem (Lu *et al.,* 2019). The economic recession created a turbulent business environment for QS practices.

Furthermore, the turbulent business environment creates challenges for QS practices such as skills shortage due to loss of talents to other geographical locations with better job prospects; difficulty in accessing capital for expansion and growth, internationalisation, and fee competition (Frei, 2010). In Ireland, the economic recession created a turbulent business environment that poses challenges to Irish QS practices such as skills shortage, high construction cost, tender price inflation, and high demand for construction services (Murphy, 2018; SCSI and PwC, 2017). Though studies have investigated the impact of the economic and financial crises on the QS profession, including Irish QS practices, there is a limited analysis and discussion on the nature of strategic choices in QS practices. Thus, this paper focuses on strategic choices; strategic change, and the impact of the turbulent business environment on QS practices in Ireland.

The Strategy Process

The strategic process entails the strategic choices that organisations make in order to reach their goals. Strategic choices focus on decision-making about the future and the response of firms to the business environment (Johnson *et al.,* 2008). Corporate strategy is the determination of organisational goals to reach the desired future state (Porter, 1998). Strategic choices at the corporate level include growth, stability, retrenchment, and combination. Strategic choices at the corporate level are critical to the effective use of resources and the direction of business level strategies to create a

competitive edge over rivals (Barney and Clarke, 2007). The business level strategy focuses on how a particular unit of a business organisation competes in an industry and how the organisation seeks to achieve its corporate choice (Bowman and Helfat, 2001). Strategic choices at the business level consist of price leader, differentiation, focus, and stack in the middle (Porter, 1998). The increasing uncertainties in business settings create challenges for making effective strategic choices in QS practices; hence, the paper adopts the research method below to explore the strategic options of QS practices in Ireland.

RESEARCH METHOD

This research adopts a mixed method comprising quantitative and qualitative approaches. The quantitative approach used a structured survey questionnaire while the qualitative used semi-structured interviews to collect data from senior managers in Irish QS firms. This paper focuses on the quantitative aspect, which is the first phase of the research while the second qualitative phase is ongoing.

The target participants are registered senior QS members of the Society of Chartered Surveyors Ireland (SCSI). The questions in the survey questionnaire were both open-ended question which seeks to ascertain the drivers of strategic change and closed-ended questions with variables adapted from the review and synthesis of the literature on the turbulent environment; the strategy process in a turbulent environment and the strategic response of organisations. The questions focused specifically on the impact of the turbulent environment on Irish QS firms and the various strategic responses that Irish QS practices adopt in order to survive in a turbulent environment.

During the design of the survey questionnaire, a turbulent environment was defined in terms of uncertainties, and this ensured that respondents easily understood and related their experiences with the term 'turbulent environment.' This approach to the definition of a turbulent environment during the questionnaire design is consistent with Singla *et al.,* (2018); Yasir *et al.,* (2017); Day and Schoemaker (2016), that define a turbulent environment as market fluctuations; rapid technological changes; complexity and volatility.

The nominal and 5-point Likert scales were used to measure the responses of participants in the survey. The purposive sampling technique and online survey tools were used to administer the questionnaire to 350 participants obtained from the database of SCSI after a thorough cleaning to ensure that only the desired participants were selected for the survey. The exclusion criteria for the cleaning of the database include QSs working in public institutions; educational institutions; non-construction organisations; QS that are self-employed; and QSs working outside Ireland.

Purposive sampling is a careful selection of participants due to the suitability of their qualities and experiences for a particular study (Etikan *et al.,* 2016). In this study, senior QSs were selected for participation because of their position in top management and who have several years of experience in the strategic planning process in their firms. One hundred and two usable questionnaires were returned for analysis with a response rate of 26 per cent. Descriptive statistics were used to undertake the analysis of the data collected. The specific descriptive statistical tools used include percentages; mean; median and standard deviation.

DISCUSSION OF RESULTS

Strategic Choices: Corporate and Business Level Strategies

This section of the paper focuses on the strategic choice of QS practices at the corporate and business levels. The strategic choices examined in this section are crucial for decision-making in QS practices, especially those operating in a disruptive business environment by focusing on the choices in table 1 below.

Table 1: Corporate and business level strategies in QS firms

A. Corporate Level Strategy	Percentage (%)
1. Seek to maintain our current market position, despite a rapidly changing the competitive environment	37.37
2. Seeking to expand into new growth sectors/markets	42.42
3. Rationalising/downsizing current practice in pursuit of increased efficiency	9.09
4. Combination of two of the above	11.11
Total	100
B. Business Level Strategy	
1. Strive to achieve low cost of service provision than competitors	17.53
2. Differentiate services from rivals to make it appealing to clients	53.61
3. Focus on a narrow segment of the market with lower cost	5.15
4. Concentrate on a narrower segment of services	10.31
5. Combine two of the strategic options above	13.40
Total	100

Table 1 indicates that corporate decision makers in QS practices are seeking to expand into new growth sectors or markets of the construction industry. In addition to the expansion, QS firms are focusing on maintaining their current market position, despite a rapidly changing competitive environment. Expansion into new markets and sectors has the potential to increase the client base of QS practices as they have the opportunity to be engaged by more clients than their competitors and its benefits are noted by Rottig and Oliveira (2019) such as increasing sales, profits, new markets, stocks, customers, and financial viability of the business. In table 1, more than half of the QS practices involved in the study differentiate their services from that of their rivals, to make their services more appealing to clients.

Participants' responses in Table 1 indicates a combination of business level strategic options. This combination consists of differentiation with a narrow segment of services; a low-cost strategy with differentiation; low cost with a narrow segment of the market; and a focus strategy on low cost and a narrow segment of services with a concentration on a narrow segment of services. Thus, this shows that QS practices at operational level adopt more than one option to address a turbulent business environment. At the business level, QS practices seek a higher level of differentiation of their service provision to clients in order to create value and avoid price/fee competition. Thus, corporate level choices in QS practices focus on expanding into new markets and sectors, and their business level choices seek to differentiate professional services offered to clients. In addition to exploring the strategic choices at both corporate and business levels, the next section of this research examines strategic changes in QS practices over the last 5 years.

Strategic Changes Over the Last 5 Years

Table 2 demonstrates that the majority of QS practices involved in the study indicate that their strategy has not changed over the last 5 years. This implies that the majority of QS practices maintain both their corporate and business level strategic choices and are not making strategic decisions that will enable them to respond to a rapidly changing business environment. However, 25 percent, and 12 percent of respondents, respectively, indicate that their strategic choices have changed at the corporate and business level in the last 5 years. Strategic change signifies the purposeful choices of organisational actors' intentions to reach their goals against the backdrop of environmental forces (MacKay and Chia, 2013). Hence, the result in Table 2 below suggests that the majority of QS practices have not made choices over the last five years that will enable them to reach their goals in a disruptive environment.

Table 2: Strategic changes in the last 5 years

Strategic changes over the past 5 years	Yes	No
1. Corporate level strategy	25.25%	74.75%
2. Business level strategy	12.24	87.76

Participants' responses to an open-ended question indicate the drivers of strategic change corporate and business level. The main drivers of strategic change at the corporate level include economic recovery that presents QS practices with more opportunities, internationalisation and the need to diversify into other markets or sectors. The main drivers of change in business level strategy as indicated by participants in this study include the need to focus on new services such as outsourcing; design service and water management.

Impact of Turbulent Environment on Strategic Process

This section discusses the impacts of a turbulent business environment on the strategic processes of QS practices in table 3 below.

Table 3: Impact of turbulent environment on strategic process in QS practices

Impact of Turbulent Environment	Mean	Median	Standard Deviation
1. Impacted how we make key decisions	3.98	4.00	0.81
2. Resulted in a change in our organisational goal	3.70	4.00	0.82
3. Required greater involvement of our staff in the strategy process	3.21	3.00	0.83
4. Reduced the time horizon/cycle for strategic decision making	3.20	3.00	0.85
5. Resulted in greater resource efficiency (e.g. staff, operational costs)	3.61	4.00	0.88

Table 3 demonstrates that a turbulent environment has an impact on the strategic planning process in QS practices, as the mean values of all the variables are above 3.00. Considering the differences between the mean and median values of all the variables in Table 3, the results show that there is less variability in the responses of participants involved in this study suggesting a symmetrical distribution of the data and the absence of outliers. The standard deviation shows there is a consistency of responses for all participants involved in the study. The critical components of a turbulent environment include market fluctuation and rapid technological change. Therefore, the strategy process of QS practices must include choices that address the tender price inflation; financial difficulties, and the allocation of resources.

The results in Table 3 suggest that there is greater involvement of staff in decision making by QS firms. Increased involvement of staff in the strategy process suggests the active participation of individuals in the strategic process of QS practices involved in the study. The involvement of staff in the strategy process leads to the effective gathering of information from staff and other sources that might not be available to senior managers to make choices during the strategy process of QS practices.
The involvement of QS practices in research and development culminates with the effective use of the knowledge and expertise of their staff and leads to a reduction in operational costs. According to Perrott (2009), increasing environmental turbulence creates challenging strategic issues that require frequent strategic planning. This phenomenon raises the issues of the time horizon for the strategic planning process in organisations. Respondents note that the strategic planning horizon in QS firms has reduced due to environmental turbulence. A reduction in the time horizon or cycle for strategic decision-making as the result shows in Table 3 indicates that QS practices are operating in environment that is rapidly changing leads to decision-making on ad hoc basis to address issues that emerge.

CONCLUSION

The results of this study demonstrate that a turbulent business environment influences the strategy process of QS practices. Four key findings of the study include the strategic choice of QS practices at the corporate level focuses on expansion into new growth sectors/markets; the main strategic option at the business level of QS practices is differentiation of services provided to clients. The study unravelled that majority of QS practices have not changed their corporate and business level strategies over the past five years in order to respond to environmental forces. Strategic change among few of the QS practices is driven by the opportunities of the economic recovery, internationalisation, and diversification into new markets or sectors. These findings differ from existing studies that focus on strategic choice without focusing on whether they have changed concerning the influence of environmental forces on QS practices. A turbulent environment causes changes in organisational goals of QS firms Thus, QS practices need to adopt strategies that enable them to respond to changes in their businesses.

Therefore, this requires the involvement of employees within the firm to ensure their active participation. The ability of QS practices to survive in a turbulent environment depends on their ability to respond to a rapidly changing business setting in order to capture potential opportunities. The response strategies of QS practices operating in a turbulent environment must emphasise four key issues. The first critical issue includes differentiation through the development of new and innovative services that address the challenges of QS practices in a rapidly changing competitive business environment. In addition to developing and seeking a market for new services, QS practices must endeavour to develop strategies that enable them to maintain their existing base of clients. Since this study is limited as far as developing the capabilities of QS practices in disruptive settings is concerned, a future research agenda focusing the dynamic capabilities of QS practices, particularly at the qualitative phase as indicated in the methodology of this paper will be appropriate.

REFERENCES

Andrews, R, Boyne, G, Law, J and Walker, R (2005) External constraints on local service standards: The case of comprehensive performance assessment in English local government, *Public Administration*, 83(**1**), 639-656.

Ashworth, A, Hogg, K and Higgs, C (2013) *Willis's Practice and Procedure for the Quantity Surveyor 13th Edition*, Chichester: Wiley-Blackwell.

Ashworth, A (2010) *Cost Studies of Buildings 5th Edition*. Harlow: Prentice Hall.

Barney, J B and Clark, D N (2007) *Resource-Based Theory: Creating and Sustaining Competitive Advantage*. Oxford: Oxford University Press.

Bowman, E H and Helfat, C E (2001) Does Corporate Strategy Matter? *Strategic Management Journal*, 22(**1**), 1-23.

Boyne, G A and Meier, K J (2009) Environmental turbulence, organizational stability and public service performance, *Administration and Society*, 40(**8**), 799-824.

Castañer, X and Yu, H (2017) The role of middle and top managers in the strategy process, *In*: S W Floyd and B Wooldridge (Eds.) *Handbook of Middle Management Strategy Process Research*, UK: Edward Elgar Publishing Limited, 13-32.

Day, G S and Schoemaker, P J H (2016) Adapting to fast-changing markets and technologies, *California Management Review*, 58(**4**), 59-77.

Dess, G and Beard, D (1984) Dimensions of organizational task environments, *Administrative Science Quarterly*, 29(**1**), 52-73.

Etikan, I, Musa, S A and Alkassim, R S (2016) Comparison of convenience sampling and purposive sampling, *American Journal of Theoretical and Applied Statistics*, 5(**1**), 1-4.

Fernandez, S (2005) Developing and testing an integrative framework of public sector leadership: Evidence from the public education arena, *Journal of Public Administration Research and Theory*, 15(**1**), 197-217.

Heinrich, C and Fournier, E (2004) Dimensions of publicness and performance in substance abuse treatment organizations, *Journal of Policy Analysis and Management*, 23(**1**), 49-70.

Huy, Q N and Guo, Y (2017) Middle managers' emotion management in the strategy process, *In*: S W Floyd and B Wooldridge (Eds.) *Handbook of Middle Management Strategy Process Research*. UK: Edward Elgar Publishing Limited,133-153.

Johnson, G, Scholes, K and Whittington, R (2008) *Exploring Corporate Strategy*. London: Pearson Education Limited.

Khandwalla, P (1987) Generators of pioneering innovative management: Some Indian evidence, *Organization Studies*, 8(**1**), 39-59.

Li, D and Liu, J (2014) Dynamic capabilities, environmental dynamism and competitive advantage: Evidence from China, *Journal of Business Research*, 67(**1**), 2793-2799.

Lu, W, Lai, C C and Tse, T (2019) *BIM and Big Data for Construction Cost Management*. New York: Routledge.

MacKay, R B and Chia, R (2013) Choice, chance and unintended consequences in strategic change: A process understanding of the rise and fall of Northco Automotive, *Academy of Management Journal*, 56(**1**), 208-230.

McKelvie, A, Wiklund, J and Brattström, A (2018) Externally acquired or internally generated? Knowledge development and perceived environmental dynamism in new venture innovation, *Entrepreneurship Theory and Practice*, 42(**1**), 24-46.

Miller, J H and Page, S E (2007) Complex adaptive systems: An introduction to computational models of social life, Cambridge, MA: Princeton University Press.

Murphy, R (2018) Employment opportunities and future skills requirements for surveying professions 2018-2021. Available from https://www.scsi.ie/education_events/employment_opportunities_and_future_skills_requirements_for_surveying_professions_report_20182021_ [Accessed 26/06/2019].

Nolan, B and Voitchovsky, S (2015) *Job Loss by Wage Level: Lessons from the Great Recession in Ireland*. UCD Geary Institute for Public Policy Discussion Paper Series, Geary WP2015/19 Available from www.ucd.ie/geary/static/publications/workingpapers/gearywp201519.pdf [Accessed: 28/06/2019].

Paroutis, S, Bennett, M and Heracleous, L (2014) A strategic view on smart city technology: The case of IBM Smarter Cities during a recession, *Technological Forecasting and Social Change*, 89(**1**), 262-272.

Perrott, B E (2009) Managing strategy in turbulent environments, *Strategic Direction*, 25(**5**), 1-10.

Peteraf, M A (1993) The cornerstones of competitive advantage: A resource-based view, *Strategic Management Journal*, 14(**3**), 179-191.

Porter, M E (1998) *Competitive Advantage of Nations*. New York: The Free Press.

Rottig, D and de Oliveira, R T (2019) International expansion of Chinese emerging market multinational corporations to developed markets: A qualitative analysis of post-acquisition and integration strategies, *In*: *Chinese Acquisitions in Developed Countries*, Cham: Springer, 37-53

SCSI and PwC (2017) SCSI/PwC Construction Survey Report 2017 Available from https://www.pwc.ie/publications/2017/scsi-pwc-construction-survey-report.pdf [Accessed 14/05/2019].

Singla, A, Sethi, A P S and Ahuja, I S (2018) A study of transitions between technology push and demand pull strategies for accomplishing sustainable development in manufacturing industries, *World Journal of Science, Technology and Sustainable Development*, 15(**4**), 302-312.

Stolyarov, II G (2005) *Austrian Economics and Kirznerian Entrepreneurship*, The Free Quebecois. Available from http://www.quebecoislibre.org/05/051215-2.htm [Accessed 28/03/2019].

Tansey, P, Spillane, J P and Meng, X (2014) Linking response strategies adopted by construction firms during the 2007 economic recession to Porter's generic strategies, *Construction Management and Economics*, 32(**7-8**), 705-724.

Thompson, A, Peteraf, M, Gamble, J and Strickland III, A J (2014*) Crafting and Executing Strategy: the Quest for Competitive Advantage: Concepts and Cases 19th Edition*. New York: McGraw-Hill Irwin.

Towey, D (2012) *Construction Quantity Surveying: A Practical Guide for the Contractor's QS*. New Jersey: Wiley and Sons.

Vecchiato, R (2015) Strategic planning and organizational flexibility in turbulent environments, *Foresight*, 17(**3**), 257-273.

Frei, M (2010) Implications of the global financial crisis for the quantity surveying profession Available from www.icoste.org/Frei.pdf [Accessed: 12/06/2019].

Wong, S K-S (2014) Impacts of environmental turbulence on entrepreneurial orientation and new product success, *European Journal of Innovation Management*, 17(**2**), 229-249.

Yasir, M, Majid, A and Yasir, M (2017) Entrepreneurial knowledge and start-up behaviour in a turbulent environment, *Journal of Management Development*, 36(**9**), 1149-1159.

SUPPLY CHAIN

UNDERSTANDING SUPPLY CHAIN INTEGRATION AS RECOUPLING

Lasse Mann Fredslund[1], Stefan Christoffer Gottlieb[2] and Roine Leiringer[3]

[1&2]*Department of Building Technology and Management, Danish Building Research Institute, Aalborg University, A.C. Meyers Vænge 15, DK-2450 Copenhagen SV, Denmark*

[3]*Department of Real Estate and Construction, The Faculty of Architecture, The University of Hong Kong, Pokfulam, Hong Kong.*

The Danish construction industry commonly addresses supply chain issues at the project level by focusing on practical problems on site. In consequence, the industry dedicates considerable resources on fighting day-to-day issues instead of embracing a more cross-organizational approach of Construction Supply Chain Management (CSCM). In this paper, we examine the attempts of one of Scandinavia's major contractor groups to achieve CSCM integration and align cross-organizational practices of the supply chain. We present a case study of two subsidiaries in the group using data from observations, surveys and interviews. Drawing on Neo-institutional theory with emphasis on the concepts of coupling and decoupling, we examine the interplay between institutional pressure and organizational responses. In our discussion, we argue that the coordination of the supply chain is decoupled from the strategic level through its constricted focus on the performance of specific projects. We then go on to illustrate how the company's efforts centre on assuming a role as CSCM integrator by involving key stakeholders of the supply chain to recouple weak links between decision-making and organizational practices. In conclusion, we argue that the company attempts to achieve CSCM integration by generating market-legitimacy. However, the constant creation of new project organizations, the existence of decentralized supply networks as well as informal authority of project managers to select or deselect procurement policies leads to various types of organizational decoupling. Accordingly, there exists a competing environment of conflicting demands and divergent incentive structures, which is an on-going challenge for the necessary alignment of cross-organizational CSCM integration.

Keywords: CSCM, decoupling, recoupling, productivity and institutional theory

INTRODUCTION

The project-based and fragmented construction industry has frequently been a target of instrumental reform initiatives based on the practices of other more integrated industries (cf. Fernie *et al.,* 2006). Since the 1980s, several initiatives have been launched to mature supply chain relations, focusing on e.g. risk sharing, cost transparency, common objectives, strong communication as well as strategic alliance across different projects (Vrijhoef and Koskela 2000). All these elements are indicators of a high level of Construction Supply Chain Management (CSCM) maturity and trust in the supply chain and are believed to positively affect the

[1] laf@sbi.aau.dk

Fredslund, L M, Gottlieb, S C and Leiringer, R (2019) Understanding Supply Chain Integration as Recoupling *In:* Gorse, C and Neilson, C J (Eds) *Proceedings of the 35th Annual ARCOM Conference,* 2-4 September 2019, Leeds, UK, Association of Researchers in Construction Management, 801-810.

performance of complex construction projects (Meng *et al.,* 2011). Thunberg and Fredriksson (2018) for example suggest that CSCM can increase productivity by addressing supply chain-related problems as distrust, lack of information, poor site logistics, and supplier and subcontractor exclusion in the planning process. Indeed, several studies indicate that these interlinked problems affect the construction process negatively by causing delays, quality issues and cost overruns (Vrijhoef and Koskela 2000; Fredslund and Gottlieb 2018). This is important, as suppliers and subcontractors commonly undertake 60-80% of the work undertaken on construction projects (Ekeskär and Rudberg 2016) accounting for approximately 80-90% of the costs (Karim *et al.,* 2006).

However, the impact of CSCM on productivity has been difficult to ascertain. In no small way, this is due to the peculiarities of the industry, which "faces wide fluctuating demand cycles, project-specific product demands, uncertain production conditions and has to combine a diverse range of specialist skills within geographically dispersed short-term project environments" (Dainty *et al.,* 2001: 163). Instead of reaping the benefits of cross-organizational collaboration, construction supply chain efforts have mainly focused on hands-on problems and firefighting at the project level (Thunberg and Fredriksson 2018). Dainty *et al.,* (2001) emphasize substantial contradictions between CSCM policies and their enactment at the project level, highlighting the need for alternatives to release the important potential of interplays between central and local purchasing functions within project-based organizations. Briscoe and Dainty (2005) even go so far as to suggest that the construction industry may never grasp the full potential of CSCM integration.

In the literature on organizational institutionalism, society is believed to be characterized by the existence of rationalizations about what creates a prosperous organization, which are often followed for reasons of legitimacy rather than efficiency (Meyer and Rowan 1977). In consequence companies may experience dilemmas or conflicts leading to a decoupling of formal policies from daily practices, or an opaque relationship between practices and outcomes. This explains the seemingly paradoxical counterproductive relationship between policies and action that has been observed in previous studies of CSCM (cf. Fredslund and Gottlieb 2018). The aim of this paper is to examine CSCM from a perspective of Neo-institutional theory by drawing on the concepts of 'decoupling' and 'recoupling'. We explore instances of organizational decoupling in a large contracting company and discuss their consequences in relation to the company's efforts to achieve supply chain integration.

We start by describing the theoretical perspective and the methodology of the inquiry. Next, we empirically analyse the context of the company and the context of the primary case organization to understand organizational issues in relation to CSCM integration. Then, we discuss what form of decoupling is implicated and what are the consequences in terms of project productivity and long-term performance of the company. On this basis, we discuss how a major contractor engages in recoupling activities by aligning policies, practices and the intended outcome of the company. Finally, we conclude by discussing how decoupling awareness and recoupling processes are crucial when implementing CSCM in major contracting companies, and the importance of the contractor recognising its focal role as the integrator.

We apply Neo-Institutional Theory (NIT) with emphasis on the concepts of coupling and decoupling in an analysis of integrating CSCM policies into a major contracting company. Hallett (2010) argues that most research on couplings in institutional

organizational research has focussed on how industries, or organizations, are loosely or tightly coupled at a specific point in time. In contrast, we draw on the less used notion of 'recoupling' to describe the "processes through which formal policies and daily activities move from being disconnected to being closely linked" (Bromley and Powell 2012: 11). In doing so, we adopt a more processual and practice-based view on organizational change than has traditionally been the case in NIT studies (Chan 2018).

Originally, institutional theory focused on explaining economic efficiency by rational actions of society. However, this narrow reasoning was not enough in the analysis of social activities evolving the theoretical field to contain features of political science and sociology like rules, culture and behaviour as drivers or pillars of social reality and change (Scott 2014). Hence, a central idea of NIT is the acknowledgement of the existence of institutional pressure that shapes the everyday life of organizations and individuals. In their seminal work, Meyer and Rowan (1977) argued that many formal organizational structures arise as reflections of rationalized institutional rules or 'myths' that exist in society about what creates a prosperous organization. Rationalized myths are a source of isomorphism, i.e. a part of the institutional pressure that affect organizations and make them become formally similar over time (Boxenbaum and Jonsson 2017). Isomorphism can be divided in three different ideal forms i.e. coercive, mimetic and normative. As such, organizations may be forced to accept certain forms through regulations, or they can imitate others based on success and legitimacy in the market. However, the narrow implications of isomorphism are a simplistic expression of a much more complicated social reality. Organizations may appear similar, yet at the operational level they respond in many different ways regardless of comparable formalities (Fredslund *et al.,* 2019). The reason for these differences is that formal policies are not necessarily integrated into daily practices. Thus, formal policies that organizations are pressurized to adopt to gain legitimacy do not necessarily constitute an effective approach leading to organizations engaging in decoupling by "building gaps between their formal structures and actual work activities" (Meyer and Rowan 1997: 341). Bromley and Powell (2012) identified two distinctive forms of decoupling relative to an ideal organization where formal policy, daily practices and intended outcomes are aligned. The first is the policy-practice decoupling where policies are disconnected from daily practices and the intended outcome may or may not be linked. The second type is the means-ends decoupling where policies are realized in practice, however loosely tied to the intended outcome resulting in little or no relation.

By engaging in decoupling, organizations may gain legitimacy while maintaining operational efficiency. Nevertheless, gaining legitimacy without adapting policies accordingly could critically affect the integrity and long-term performance of the company. Boxenbaum and Jonsson (2017) stress that decoupling is more common among organizations that are subject to a strong pressure from the institutional environment to implement novel policies. As such, decoupling might occur if organizational members distrust the capabilities of the formal policies, or if members do not believe in the effectiveness of the proposed practices within the organization. Organizational members can decide to engage in decoupling activities and often members renounce these activities if it requires them to deviate from their normal professional roles. According to Fiss and Zajac (2004), organizational alliances can mitigate the negative effects of institutional pressure and decoupling through committed actions concerned with establishing "tight couplings where loose couplings

were once in place" (Hallett 2010: 54). Binder (2007) emphasizes, that the recoupling process is a local response to institutional pressures and can be seen as an interface between micro and macro aspects that links organizations to their institutional environment. By its very nature, recoupling occurs at local organizational levels involving the relationship among individuals, the organization and the institutional environment. Hence, scrutinizing recoupling requires data of these relationships to capture the actual dynamics and mechanisms of the social context affecting the organization in enquiry (Hallett 2010).

METHODOLOGY

The paper draws on a two-year study rooted in the strategic procurement department (SP) of the MTH Group, which is one of the Nordic region's leading construction and civil engineering companies consisting of seven independent subsidiaries with approx. 3900 employees. The method applied comprise of (i) interviews with and observations of the top management and other relevant procurement members of the group; and (ii) a case study of two different subsidiaries of the Group (the MT Højgaard organization and the E&P TRUST Partnership organization) to frame a comparative study of organizational variations of CSCM practices. These two subsidiaries were chosen as they have followed different policies for supply chain integration. The MT Højgaard organization is the primary unit of analysis, as SP's efforts to create a comprehensive and participatory process for developing CSCM practices in the entire Group play out in this organization. The secondary unit of analysis is the E&P TRUST Partnership organization. This organization is already developing CSCM practices by addressing issues such as cost transparency, project portfolios, sharing risks and benefits, thus constituting a source of insights into how CSCM can be developed within the Group.

The case study includes a questionnaire survey with 80 respondents quantifying the CSCM maturity level within the Group as well as qualitatively identifying generic or perceived issues related to CSCM integration. The survey was inspired by elements of Meng *et al.,* (2011) four levels of CSCM maturity, i.e. 1. Price competition, 2. Price and quality competition, 3. Project partnerships, and 4. Strategic alliances. The survey also probed the respondents' understanding of current group policies and practices in relation to e.g. procurement process, cost transparency, cooperation, feedback, trust, conflict management, communication, risks and benefits. In other words, the survey investigated existing rationalisations about the institutional context in which the group and the case organizations operate. Furthermore, 30 qualitative interviews concerning decoupling aspects and CSCM integration issues were conducted, targeting the relationship between suppliers, organizational policies and the practices of specific projects. Finally, construction site observations and meeting attendance (e.g. client meetings and construction meetings) have been used to nuance the findings and provide insights into the daily realities of complex building projects. The combined empirical data is used to analyse the CSCM maturity level in the group, and how the case organizations respond to the institutional pressure on increasing productivity through CSCM integration.

FINDINGS AND ANALYSIS

In this section, we first describe the institutional context under which the MTH Group operates. Then, we analyse the procurement process in the MT Højgaard organization to understand how the organization respond to the institutional pressure, and to identify instances of organizational decoupling and their consequences. On this basis,

we discuss how policies, actions and outcomes can be recoupled to developing a cross-organizational CSCM integration in the MT Højgaard organization.

The Institutional context of the MTH Group

The findings from the survey portray an industry operating with CSCM maturity i.e. level 2. Price and quality competitions as basis for its supply chain relationships. The survey moreover showed that diverse perceptions about CSCM maturity is part of the institutional context as the external actors and the project level respondents had a stronger perception on the higher CSCM maturity levels (e.g. level 3. Project partnerships and level 4. Strategic alliances) than the strategic level of the case organizations. The qualitative statements gave evidence to differences between the two case organizations. The E&P Trust Partnership organization was perceived more productive due to its working relationship with equivalent suppliers across projects as the suppliers are more willing to take ownership and share competencies by prospect of future portfolio deliveries. Moreover, the financial transparency of the partnership was argued to create incentives for optimization of product deliveries and logistics, and as often positively affecting the operative performance of projects as well as suppliers' production flow.

Respondents of both case organizations stressed the issue of a lack of supplier involvement from design to project execution. In addition, inexpedient transitions between strategic activities and project performance where different interests (or logics) often collide were stated. Respondents stated that projects with a high degree of alignment between organizational levels would continuously outperform projects characterized by colliding aspects. A frequent argument was that colliding interests between organizational levels result in diverse and random ownership to the supply chain, in conjunction with suppliers not being committed to the projects as they can be deselected regardless of entering framework agreements. In other words, the survey indicated that substantial strategic activities and long-term supplier relations are decoupled at the project level to save costs on specific projects (e.g. by circumventing framework agreements). Another generic finding is that across companies, managers, craftsmen, and suppliers prioritize known and trusted relationships at the individual level over organizational affiliations and formal polices leading to the creation of informal supply networks.

The survey findings indicate a relatively modest CSCM maturity level. However, analysing core components of CSCM (e.g. common objectives, cost transparency, trust, strategic alliances, sharing risks and benefits) reveals a more critical perspective. Thus, a strong focus on unit costs instead of multi criteria (e.g. logistics, supplier capacity and competencies) across many projects negates the total economic and holistic perspectives of CSCM. Nonetheless, close collaboration and problem solving at the project level were identified as common practices, which highlights a stronger orientation on partnerships relations during project execution. Furthermore, respondents acknowledged that the extensive sub-optimization of own project objectives results in the absence of early risk warnings and identifications through the supply chain, which makes procurement practices such as 'just in time' deliveries extremely vulnerable. Moreover, risks are often allocated to the weakest party and there are limited benefits associated to these risks, which arguably counteracts strong cooperation and common objectives in the supply chain. Findings also indicate a high degree of personnel mobility both at the suppliers and at the projects creating low credibility and distrust between actors. Furthermore, limited price and cost

transparency between parties, lack of common understandings, and diverse incentive structures lead to cross-organizational contradictions between the suppliers, the company and the projects. Finally, respondents stressed that the fragmented environment, low earning margins and the constant creation of new project organizations are the main barriers to CSCM integration.

The Procurement process in the MT Højgaard organization

The Strategic Procurement Department

The Group Procurement Department consists of a Strategic Procurement department (SP) and a Project Procurement department (PP). SP is accountable for approx. 200 framework agreements representing 25% of the MTH Group purchasing volume. The rationale behind the set-up is to coordinate the purchasing volume across the many projects of the Group to obtain lower prices and the best possible contact terms. Furthermore, the setup is intended to enable SP to continuously benchmark price levels across projects, evaluate supplier performance and to assist specific projects in the event of a dispute with a contract supplier. SP works with different categories of suppliers, with each category (e.g. concrete, iron and timber) consisting of typically 3-5 framework agreements with selected suppliers. Thus, a competitive environment is ensured by the option to choose the best price among the 3-5 categorized framework agreements. In some cases, pure price competition will be used, e.g. basic products such as screws or bolts. In other cases, additional evaluation criteria are used to ensure e.g. supplier capacity, cooperation, logistics and total cost perspectives especially in relation to complex products like concrete elements. Thus, the framework agreements are a strategic approach to locking and squeezing overall prices by favourable market positions as well as reducing risks by embracing e.g. regulations of safety, payment terms, deliveries and CSR requirements. Typically, when suppliers enter a framework agreement, they pay a 'loyalty bonus' with a formal rate of 2-6% of their total turnover for their trades with the MT Højgaard organization, which finances SP entirely.

In sum, the interviewees acknowledge the expertise of SP. However, the informants stress that the loyalty bonuses associated to the framework agreements give rise to organizational contradictions by blurring price transparency and by being perceived as a costly element for the production. In addition, the informants claimed to often experience better prices and logistics when bypassing the framework agreements and the embedded bonus. SP is aware of the of these perceived issues and work to align organizational levels by communicating the benefits of the framework agreements as well as over time remove the bonuses completely, which will generate a need to find alternative financing of SP.

The Project Procurement Department

The Project Procurement Department (PP) is divided into different professional subject areas (e.g. steel, facades, technology, and concrete elements) and supports the tender process of projects by scrutinizing and optimizing offers from the suppliers. Moreover, PP continuously measures project savings and satisfaction in relation to specific tender cases. Thus, the formal justification of PP is the collection and centralisation of specialist knowledge that can be brought into play across parallel projects within the organization. As such, updated knowledge and the accumulation of experience are formally ensured across projects in the MT Højgaard organization. PP is financed through the invoicing of time spent on tendering on specific projects. However, PP experience challenges with getting involved in the tendering, as there is

a tendency to use the production department's own employees for this. While employees in the production department express an acknowledgement of the expert competence of PP and the role PP plays in the tendering process, a policy-practice decoupling however occur due to an expressed missing focus on specific project requirements and needs. The production department stresses that divergent incentive structures and lack of capacity to get involved in specific project processes such as logistics or assembly limit PP's role in the process. In other words, PP are criticised for not securing deals that accommodate the project-specific objectives. As such, the production department prefer to work with well-known suppliers who are selected on basis of past working experience and they do not perceive PP's more generic approach to support these important relations as they focus narrowly on unit prices. The production department, however, finds these specific necessities crucial to realize profit on the individual project. This highlights the importance of maintaining informal supplier-networks from the perspective of the production department. In contrast, PP employees argue that some project managers have turned over the obligation of the tendering task and the procurement activities to PP due to lack of competences or in order to focus their efforts on the practical project execution. Thus, on the one hand, PP argues for a centralization of the procurement function while emphasizing that it has created positive results in relation to tendering tasks, purchasing processes and project performance. On the other hand, project managers' preference has been solely on managing and coordinating project activities.

To summarize, different forms of decoupling characterize the procurement organization, which has resulted in contrasting opinions on whether to centralize or decentralize the purchasing function. An example of a means-end decoupling is when polices (i.e. framework agreements) are integrated into practice but have an adverse effect on project performance and logistics. Another example is a policy-practice decoupling where distrust of formal procurement activities leads to the creation of informal supply-networks at the project-level.

DISCUSSION

Institutional pressures explain why organizations routinely try to adopt policies without the necessary capacity to integrate them into practice (Boxenbaum and Jonsson 2017). This results in policies getting a more ceremonial character within organizations, which is currently the case with CSCM integration in the MT Højgaard organization. We will now discuss what forms of decoupling are implicated in the procurement process of the MT Højgaard organization, and how an awareness of decoupling and recoupling can contribute to create cross-organizational alignment.

The fragmented nature of the construction industry and the constant creation of new project organizations makes it difficult to generate one generic CSCM policy unless it can accommodate these constant changing circumstances. The procurement policies of the MT Højgaard organization are to some extent decoupled from the daily practices of projects, due to the informal authority of project managers to select or deselect procurement policies and suppliers, which they consider appropriate regardless of organizational affiliations. As such, the production department is maintaining decentralized supplier-networks while neglecting organizational policies. The corollary is that the MT Højgaard organization's ability to manage and coordinate the procurement activities within the organization can be questioned. As such, there exists a competing environment of conflicting demands within the organization, which increases the focus on sub-optimization and leads to lack of common understandings.

The empirical findings point out several instances of organizational decoupling the most prominent of which is the policy and practice decoupling, where conflicting interests and diverse incentive structures affect the intended outcome of the MT Højgaard organization. This is due to e.g. divergent perceptions, informal supplier-networks, the bypassing of strategic activities, and a lack of long-term focus at the project level. The MT Højgaard organization have already tried to address these issues with a formal stage-gate model advancing cross-organizational alignment, however without achieving any tangible results. The model can therefore be interpreted as another example of policy-practice decoupling.

The process of decoupling in the MT Højgaard organization has led to inconsistencies between cross-organizational dimensions, which counteract core elements of CSCM, e.g. knowledge sharing, common objectives and understandings. On the one hand, there is a discussion of whether to centralise or decentralise the procurement function. This is what Frödell *et al.,* (2013) describe as two dysfunctional extremes that beneficially should be substituted with a more mediating and less integrated form of procurement process. On the other hand, organizational members also recognise the potentials of the different procurement functions within the organization and supplier competences as ingredients to increase productivity in the supply chain. This speaks for a more aligned and flexible approach for when and how to use different available policies of the organization instead of adhering to a more generic policy.

SP is aware of the forms of decoupling and the potential negative effects hereof for the long-term performances of the company. Thus, SP emphasizes that there are misunderstandings about the impact of the loyalty bonuses and the framework agreements, stressing that middle management is a barrier for a mediating and objective communication throughout the organization leading to misperceptions. Consequently, SP attempts to align organizational levels by reducing bonus levels from 2-6% to 1-2% and simultaneously channelling the bonuses back to the individual project as well as strengthening the organizational communication by creating focused reports about each project's contribution. However, we argue that this initiative reinforces organizational decoupling instead of leading to the development of a more holistic and long-term strategy of CSCM integration that can create the desired involvement of cross-organizational functions and competences of the supply chain.

The question is how the expectations and potentials of CSCM can be translated into the practical settings of the MT Højgaard organization effectively. Thus, moving from a ceremonial character to a practical integration process by local interactions of cross-organizational actors. The MT Højgaard organization has a focal role in that process by connecting external and internal actors through the accomplishment of complex building projects. SP's efforts to recouple the problematic different supply chain processes and the different actor convictions involve reorganising the procurement function, which can be accomplished through local interactions connecting key stakeholders of the supply chain. Hence, a potential recoupling strategy would involve cross-organizational actors directly in the development and integration process of CSCM to ensure commitment and capabilities to better align policies, practices and the intended outcome of complex projects and the company.

CONCLUSION

In this paper, we have introduced reflexions and considerations about the concepts of decoupling and recoupling to shed new light on the potentials and issues of CSCM integration. The study focusses on only one case company. However, the discussions

in the paper can be considered to represent generic issues across construction industries in general. We build the empirical foundation on a multi-method case study of a major contracting group's efforts to achieve CSCM integration to understand how the organization work to actively align its organizational environment. In doing so, we analysed the industry context and organizational settings to identify how decoupling is affecting the procurement function within the MT Højgaard organization. On this basis, we discussed how the MT Højgaard organization could advance CSCM integration by recoupling organizational levels through a participatory process, which addresses the alignment between procurement policies and the practice of cross-organizational actors integrating elements of CSCM, e.g. cost transparency, commend objectives, feedback systems, project portfolios and sharing risks and benefits.

The main contribution of this study is to link the concept of CSCM integration to organizational decoupling and discuss how integration activities can be understood as a process of recoupling, where formal policies, daily activities and intended outcomes become more aligned. We have analysed the procurement function of the MT Højgaard organization to understand the nuances of organizational decoupling and how a potential recoupling process could enable CSCM integration. Furthermore, we have tried to understand how current activities are reflected by rationalizing pressures at the project level, which do not necessarily constitute an effective and long-term solution for the MT Højgaard organization.

For this reason, a recoupling pilot process will take place in a near future in the MT Højgaard organization, which will reveal more insights into the components and nature of a participatory development process in relation to CSCM integration. The process of recoupling is not necessarily a panacea or remedy for all supply chain problems. Nevertheless, it is a novel attempt to gather cross-organizational actors to discuss how CSCM integration can increase productivity through the capabilities of the different supply chain actors. A potential participatory recoupling process will require as a minimum, managerial legitimacy and organizational resources as well as the will to discuss beyond organizational affiliations and boundaries, which is arguably essential for the CSCM integration.

We call for future research to scrutinize empirically how other organizations act on rationalizations in their environment to recouple policies, practice, means, and ends to release the potentials of CSCM integration.

REFERENCES

Binder, A (2007) For love and money: Organizations' creative responses to multiple environmental logics, *Theory and Society*, 36(**6**), 547-571.

Boxenbaum, E and Jonsson, S (2017) Isomorphism, Diffusion and Decoupling: Concept Evolution and Theoretical Challenges. *In:* Greenwood, R, Oliver, C, Lawrence, T B and Meyer, R E (Eds.) *The SAGE Handbook of Organizational Institutionalism*, London: SAGE Publications, 77-101.

Briscoe, G and Dainty, A (2005) Construction supply chain integration: An elusive goal? *Supply Chain Management: An International Journal*, 10(**4**), 319-326.

Bromley, P and Powell, W W (2012) From smoke and mirrors to walking the talk: Decoupling in the contemporary world, *The Academy of Management Annals*, 6(**1**), 1-48.

Chan, P (2018) change and continuity: What can construction tell us about institutional theory? *In:* Sage, D J and Vitry, C (Eds) *Societies Under Construction*, Cham: Palgrave Macmillan, 151-184.

Dainty, R J, Millett S J and Briscoe G H (2001) New perspectives on construction supply chain integration, *Supply Chain Management: An International Journal*, 6(**4**), 163-173.

Ekeskär, A and Rudberg, M (2016) Third-party logistics in construction: The case of a large hospital project, *Construction Management and Economics*, 34(**3**), 174-191.

Fernie, S, Leiringer, R and Thorpe, T (2006) Change in construction: A critical perspective, *Building Research and Information*, 34(**2**), 91-103.

Fiss, P C and Zajac, E J (2004) The diffusion of ideas over contested terrain: The (non) adoption of a shareholder value orientation among German firms, *Administrative Science Quarterly*, 49(**4**), 501-534.

Fredslund, L M, Frederiksen, N and Gottlieb, S C (2019) The hybridity of strategic partnerships and construction supply chain management. *In*: *The 10th Nordic Conference on Construction Economics and Organization*, 7-8 May 2019, Tallinn, Estonia, 1-7.

Fredslund, L M and Gottlieb, S C (2018) Engaging the construction supply chain: A pluralistic perspective. *In*: Gorse, C and Neilson, C J (Eds) *Proceedings of the 34th Annual ARCOM Conference*, 3-5 September 2018, The Queen's University, Association of Researchers in Construction Management, Belfast, UK, 352-361.

Frödell, M, Josephson, P E and Koch, C (2013) Integration barriers for purchasing organization in a large construction company: Towards requisite disintegration, *The IMP Journal*, 7(**1**), 46-58.

Hallett, T (2010) The myth incarnate: Recoupling processes, turmoil and inhabited institutions in an urban elementary school, *American Sociological Review*, 75(**1**), 52-74.

Karim, K, Marosszeky, M and Davis, S (2006) Managing subcontractor supply chain for quality in construction, *Engineering, Construction and Architectural Management*, 13(**1**), 27-42.

Meng, X, Sun, M and Jones, M (2011) Maturity model for supply chain relationships in construction, *Journal of Management in Engineering*, 27(**2**), 97-105.

Meyer, J W and Rowan, B (1977) Institutionalized organizations: Formal structure as myth and ceremony, *American Journal of Sociology*, 83(**2**), 340-363.

Scott, W (2014) *Crafting an Analytical Framework I: Three Pillars of Institutions. Institutions and Organisations*. London, SAGE Publications, 55-74.

Thunberg, M and Fredriksson, A (2018) Bringing planning back into the picture: How can supply chain planning aid in dealing with supply chain-related problems in construction? *Construction Management and Economics*, 36(**8**), 425-442.

Vrijhoef, R and Koskela, L (2000) The four roles of supply chain management in construction, *European Journal of Purchasing and Supply Management*, 6(**3-4**), 169-178.

MANAGING VULNERABILITIES AND CAPABILITIES FOR SUPPLY CHAIN RESILIENCE IN INDUSTRIALISED CONSTRUCTION

Anushika Chathurangi Ekanayake Ekanayake Mudiyanselage[1], Geoffrey Q P Shen and Mohan M Kumaraswamy

Department of Building and Real Estate, Faculty of Construction and Environment, The Hong Kong Polytechnic University, Hung Hom, Kowloon, Hong Kong

Industrialised Construction (IC), as a modern construction technology is superior to conventional cast-in-situ concrete construction in many ways and has attracted immense attention from many countries over the past two decades. This widespread interest can be largely explained by the inherent superiority of the technology and its products. However, a major challenge faced by managers of IC is to anticipate and withstand its innate supply chain disruptions. Indeed, the IC supply chain is found to be quite complex, resulting in potential disruptions that can significantly affect performance levels. This, therefore, requires a new focus on disruption management that transcends 'conventional wisdom' and standard practices. Supply chain resilience (SCR) as a focus area for a new initiative, has emerged in other industries to address supply chain related challenges in effective disruption management by calling for supply chains that are less brittle and more adaptive. There is a dearth of literature in construction SCR, while the research gap is even wider and also more critical for SCR in IC. Therefore, a systematic literature review followed by an initial empirical study with site visits were performed in Hong Kong, by gathering, analysing and consolidating the relevant research data and findings, to develop a framework that identifies and maps vulnerabilities and capabilities for SCR in IC, thereby enabling deeper examination of how best to address and manage them together and more effectively. Thus, the main thrust of this study is to propose a basic framework to enhance SCR in IC by first identifying potential supply chain disruptions; and next proposing well-informed management strategies to withstand these disruptions.

Keywords: industrialised construction, supply chain resilience, vulnerabilities

INTRODUCTION

The construction industry has suffered for decades from remarkably poor productivity compared to the other industrial sectors (Barbosa *et al.,* 2017). Hence, a recent report from the McKinsey Global Institute, suggests seven areas that can boost construction sector productivity, including improving its Supply Chain (SC) and onsite execution. According to this report, it should be possible to achieve a 5-10 times productivity boost by partially moving to a manufacturing-style production system. In this context, Industrialised Construction (IC) based on prefabricated building components and systems has emerged as an attractive approach that is perceived to improve efficiency,

[1] 17902595r@connect.polyu.hk

Mudiyanselage, A C E E, Shen, G Q P and Kumaraswamy, M M (2019) Managing Vulnerabilities and Capabilities for Supply Chain Resilience in Industrialised Construction *In:* Gorse, C and Neilson, C J (Eds) *Proceedings of the 35th Annual ARCOM Conference,* 2-4 September 2019, Leeds, UK, Association of Researchers in Construction Management, 811-820.

flow and quality of the construction (Lawson *et al.,* 2011), reduce project duration and the associated costs and, to improve the working conditions at site (Bataglin *et al.,* 2017). IC is seen as a means to address a series of dilemmas and constraints in the construction industry, including in Hong Kong (HK) IC is also envisaged to gain momentum owing to its potential benefits such as environment-friendly, better quality, cleaner and safer working environment (Li, 2016). However, the fragmented nature of prefabricated SC; design, manufacturing, transportation, and on-site assembly generates a variety of vulnerabilities in IC in HK, and these disruptions beset the industrial performance (Li *et al.,* 2016). Although conventional Risk Management (RM) is designed to help to address these vulnerabilities, it is evident that it cannot adequately address all the SC disruptions (Van Der Vegt *et al.,* 2015), hence requiring a new focus on disruption management that transcends 'conventional wisdom' and standard practices. In this context, the emerging concept of 'resilience' has recently attracted the growing interest of academic researchers and industry practitioners.

Resilience goes beyond mitigating risks. It enables organisations to deal with disruptions more effectively (Fiksel, 2015). Supply Chain Resilience (SCR) also goes beyond the traditional SC RM practices (Zavala *et al.,* 2018) and enables handling the disruptions which cannot be handled within the traditional RM framework. However, there is a dearth of literature findings on SCR in construction practices [only one publication was found; Zainal and Ingirige (2018)], and there was no known or published research found for SCR in IC. Therefore, this study aims to propose a basic framework to enhance SCR in IC by first identifying potential SC vulnerabilities; and next recommending well-informed capabilities to withstand them effectively.

LITERATURE REVIEW

Also called as the off-site construction and prefabricated construction, IC refers to structures built at a location other than the location of assembly (Gibb, 1999). IC includes various approaches: precast panels, columns and other components, prefabricated units and more recently pre-engineered modular units (Gosling *et al.,* 2016). Encouraging IC through the extensive use of pre-cast technology and minimising on-site construction, would boost the productivity of the construction industry (Barbosa *et al.,* 2017). This was recently exemplified by the Mini Sky City construction in China: A 57 storied skyscraper construction. It required 19 working days instead of more than one-year construction required by the conventional construction methods (Chang *et al.,* 2018). Besides, IC provides an effective alternative to the traditional site-based construction with improved quality, reduced waste, lowered labor requirements at site (Rwamamara, 2007), reduced lifecycle cost, improved sustainability (Gibb and Pendlebury, 2006), better controlled built environment and enhanced safety (Chang *et al.,* 2018). IC has attracted worldwide concern because of its significant role in the creation of sustainable growth (Hong *et al.,* 2018). Therefore, there is no major general argument holding back the application of IC in many countries; Japan, Singapore, UK, and USA (Jaillon and Poon, 2009). Application of IC in the HK construction industry is also not new due to its wide application in the public housing sector (Li *et al.,* 2016). However, the application of IC in HK remains at a low level compared to the other developed countries (Li *et al.,* 2016). Lack of accurate information on managing the pre-cast units, poor information sharing among the project stakeholders and fragmentation and discontinuity of the entire prefabrication SC, are the possible causes behind the issue. In IC SC, there are three phases namely; prefabrication, logistics and onsite assembly (Zhai and Huang, 2017). All these phases are fragmented and subjected to discontinuity, also given the

different stakeholders assigned to perform different tasks (Zhai *et al.,* 2017). Hence, design information should be shared in a timely manner with manufacturers without leaving ambiguities, while prefabricated elements should be received on site without any disturbances to on-site assembly, to ensure the timely completion of projects. However, disruptions such as machine breakdown, traffic jam, low efficiency of customs clearance and damages to the modular units, are common in each phase of the IC SC (Zhai and Huang, 2017). If these situations are not managed effectively and efficiently, time and cost savings from adopting IC will easily wither away. Any disturbance at any point of the IC SC will impact the entire process, since it is relatively unchangeable and fixed once scheduled (Zhai and Huang, 2017). This highlights the need for extensive SC management in IC.

Although there are numerous RM strategies applied in the construction industry to manage these disruptions (Zavala *et al.,* 2018), they involve hazard identification, risk assessment, controlled implementation and review (Pettit *et al.,* 2010) by employing empirical data, mathematical modelling and probability distributions, in making future predictions where it is highly difficult to identify all potential risks to conduct adequate risk assessments (Van Der Vegt *et al.,* 2015). Mostly, the disruptions have emerged as a set of joint events and generate cascading impacts which are hard to anticipate and predict. Indeed, these approaches are unable to respond to low-probability, high-impact disruptive events adequately, and they cannot deal with the enforceable events (Pettit *et al.,* 2010). Hence, the growing attention of academic researchers and the industry practitioners have shifted towards SCR which goes beyond the traditional SC RM practices (Zavala *et al.,* 2018) and, enables handling the disruptions which cannot be coped within the RM framework.

SCR is defined as 'the ability to react proactively to disturbances and to return to its original state or a more desirable one' (Ponomarov and Holcomb, 2009). It is the balance between vulnerabilities [key disruptions which disturb the normal construction process and are unanticipated and unplanned (Zavala *et al.,* 2018)] and the associated capabilities that enable an enterprise to anticipate and withstand vulnerabilities (Pettit *et al.,* 2013). Based on the empirical findings, Pettit *et al.,* (2013) developed a SCR assessment tool for manufacturing and service firms. Recently, considering the dynamics of SC vulnerabilities and capabilities, Zainal and Ingirige (2018) proposed a SCR framework for Malaysian public construction projects. However, less attention has been paid to researching on SCR in the construction industry (Zainal and Ingirige, 2018). As an emerging research area, the research gap is highly significant in IC, and it is essential to explore SCR in IC due to the following reasons; (a) IC SCs are complex and associated with inherent disruptions (Zhai and Huang, 2017), (b) they are also vulnerable to many unforeseeable disruptions (Luo *et al.,* 2018); (c) IC SCs are relatively fixed and unchangeable once scheduled (Zhai *et al.,* 2017) hence the disruptions may alleviate the cascading impacts; and (d) although the industry practices traditional RM approaches, they are unable to assess the SC complexities, and prepare SCs for future unknowns including black swan events. The foregoing reasons underpin the rationale and imperative for this study which aims to propose a basic framework to enhance SCR in IC for a value-added SC.

RESEARCH METHODOLOGY

This paper presents an important part of an ongoing PhD study which aims at developing an evaluation model to enhance SCR in IC in HK. Hence, this study

targets to build a basic framework for improving SCR in IC, based on the data retrieved from the published literature and then strengthen the findings through a preliminary empirical study. Therefore, an in-depth systematic review of literature through meta-analysis was first conducted as suggested by the studies of Osei-Kyei and Chan (2015) and Owusu *et al.,* (2018) to identify, retrieve, and examine the extensive literature on SC vulnerabilities and capabilities in IC SCs. This approach consisted of two phases namely; (a) searching for and identifying the targeted papers and (b) examining and analysing the selected papers. During phase 1, two broad preparatory desktop searches were conducted separately through a powerful search engine Scopus using title/ abstract/keyword search option to identify the research papers on vulnerabilities and capabilities in SCR. 139 and 167 publications on vulnerabilities and capabilities were retrieved separately from this initial search and 54 and 41 papers were filtered to the secondary screening based on an in-depth visual examination on the title/abstract/ keywords. After thorough scrutiny, 36 and 28 publications (respectively) were finally selected for further investigation and analysis. Selected publications were then subjected to the content analysis and 37 vulnerabilities, and 58 capabilities were retrieved as appropriate for this specific IC focused study.

These factors were then categorised under 6 vulnerability constructs and 12 capability constructs based on a thematic analysis process. During the thematic analysis of the variables, the authors identified identical relationships separately within these vulnerability factors and also within these determined capability factors, respectively. Hence, by adhering to the studies of Pettit *et al.,* (2013) and Zainal and Ingirige (2018); and the thematic analysis research method, identified 37 variables were categorised under six constructs.

Vulnerability Category	Explanation	Referred studies for categorisation
Project organisational Vulnerabilities	Arising from the inadequate strategic business decisions undertaken, poor management decisions and staff within the organisation and human resources availability	Pettit, Croxton, and Fiksel (2013) – 7 categories based on global manufacturing and service firms; Zainal and Ingirige (2018) – 11 categories based on Malaysian public projects; Owusu et al. (2018) - thematic analysis research method for developing constructs
External Environmental Vulnerabilities	Arising from the external environment which is beyond the SC's control	
Procedural Vulnerabilities	Arising from the operation at any node of the SC and can be considered as the process-based disruptions	
Technological Vulnerabilities	Arising from technology changes or failures in a SC	
Financial Vulnerabilities	Arising from liquidity or credit issues relating to money and poor management of monitory assets and insolvency	
Supplier/Customer Vulnerabilities	Arising from the susceptibility factors allied with suppliers and customers of the SC	

Capability Category	Explanation	Referred studies for categorisation
Flexibility	Ability to quickly mobilise resources when required	Pettit et al., (2010) – 14 categories related to the limited brands in the manufacturing industry; Zainal and Ingirige (2018) – 12 constructs related to Malaysian public projects; Owusu et al. (2018) - thematic analysis research method for developing constructs
Capacity	Availability of resources in the SC to enable continuous output in IC	
Efficiency	SC capability to produce outputs with minimum resources	
Visibility	Having knowledge on the status of current operating resources in the SC and the SC environment	
Adaptability	Ability to modify operations in response to disruptions or opportunities	
Anticipation	Ability to detect potential future disruptive events in the SCs	
Recovery	Ability to promptly return to normal operational state after a disruption	
Dispersion	SC capability which enables decentralisation of resources and clients	
Collaboration	Ability to work effectively with the other parties for mutual benefit	
Market Position	Status of an organisation or its products/services in specific markets	
Security	Ability to defend against deliberate intrusions	
Financial Strength	Capacity to absorb fluctuations in the cash flow	

Figure 1: Categorisation of factors

Similarly, 58 SCC were categorised into 12 constructs based on the study protocols and developments by Pettit *et al.,* (2010) and Zainal and Ingirige (2018) during the thematic analysis process. Figure 1 clearly explicates the categorisation process and the development of the constructs in this study. Finally, these findings contributed to developing a conceptual framework for achieving SCR in IC and furthered to a preliminary empirical study.

The qualitative approach in research facilitates distinct advantages of focusing on a specific set of people, an in-depth study on broad topics, and representing the views

and perspectives of the people (Yin, 2017). Therefore, this study adhered to a social constructionism approach by conducting in-depth expert opinion survey in collecting preliminary data to strengthen the conceptual framework and to develop a basic framework of the study. Six semi-structured interviews along with site visits were conducted of relevant industry experts in HK who were well experienced in IC for 10-30 years (Table 1 presents the interviewee profile). Collected information was analysed using N-vivo software. The interview findings provided empirical justifications of the developed constructs in the basic framework based on the actual situation in the industry. However, the ongoing research study will further follow a mixed method approach in collecting data including subject matter expert surveys and case studies to evaluate the constructs and validate the findings for HK construction industry. This paper is based on the initial results of this PhD research study and may be seen to lack dense empirical validation of the results. However, it is an essential first stage output which forms the basis for the next stage. The forthcoming sections of this paper discuss the basic framework, report the findings, and derive the conclusions with a proposed way forward.

Table 1: Profile of the interviewed experts [Note: statements by them will be cited hereafter, followed by [E1] or [E1, E2] to convey that these were by E1, or both E1 and E2]

Interviewee	Experience	Position	Organisation type
E1	27 years	Director	Government authority
E2	12 years	Assistant Project Manager	Private Contractor
E3	15 years	Project Manager	Private Contractor
E4	10 years	Site Engineer	Private Contractor
E5	30 years	Project Manager	Contractor and developer
E6	22 years	Director	Government authority

Basic Framework and Discussion

Results derived from the systematic analysis of the literature on SCR and the results of the preliminary experts' opinion survey were drawn upon to develop the basic framework as shown in Figure 2. As determined from the previous literature, there are six vulnerability constructs namely: Project Organizational; Procedural; Supplier/ customer; Technological; External Environmental; and Financial Vulnerabilities that retard the performance of IC SCs. "There must be many vulnerabilities in a project, and our team has to forecast project programme to check whether these uncertainties can be solved before the project commenced. They claim money, time and affect the completion of project sequence in the short term and the long term" [E2, E3].

External environmental vulnerabilities (disruptions from the external environment which are beyond the SC's control) can be either man-made or 'Act-of-God' situations. "Probability of happening natural disasters, terrorism/war, epidemics are very less in HK. But, political economy changes, adverse weather, initiating new regulations are much common here" [E1]. "Recently, industrialisation was highly vulnerable to the regulation and policy changes. Also, it was very prevalent to see machine breakdowns especially the tower crane breakdowns which caused delays" [E2, E3, E5]." From the last typhoon, we faced damages. We applied to recover them from insurance, so we were safe" [E2]. Although terrorism/war, political instability are ranked top in the literature (Masood and Choudhry, 2010), in IC SCs, mainly logistics are affected by the political and regulatory changes (Chauhan *et al.,* 2015) and assembly is affected by the adverse weather (Wang *et al.,* 2018). "However, the impact is lesser compared to the conventional construction" [E6].

Project organisational vulnerabilities are possible with poor management and operational issues. In IC, labor strikes, disputes are often, and significant (Wang *et al.,* 2018). Communication issues between the stakeholder's cause disputes and exert strong direct influences on other IC vulnerabilities such as design changes/variations (Luo *et al.,* 2018). Planning and scheduling errors, outsourcing also cause assembly problems and poor SC visibility (Wang *et al.,* 2018). "Labour is the problematic resource in HK. Disputes, loss of skilled labour and frauds interrupt the project execution" [E1, E6]. "Inadequate information exchange causes serious design changes and delays" [E5]. "We recently faced such a delay in constructing a column since the allocated gap was not enough to assemble" [E2, E4]. "Mostly they are tolerance issues in IC. If one unit is cast with 1mm error, the process becomes vulnerable to assembly problems which cause cost, time overrun" [E3, E5].

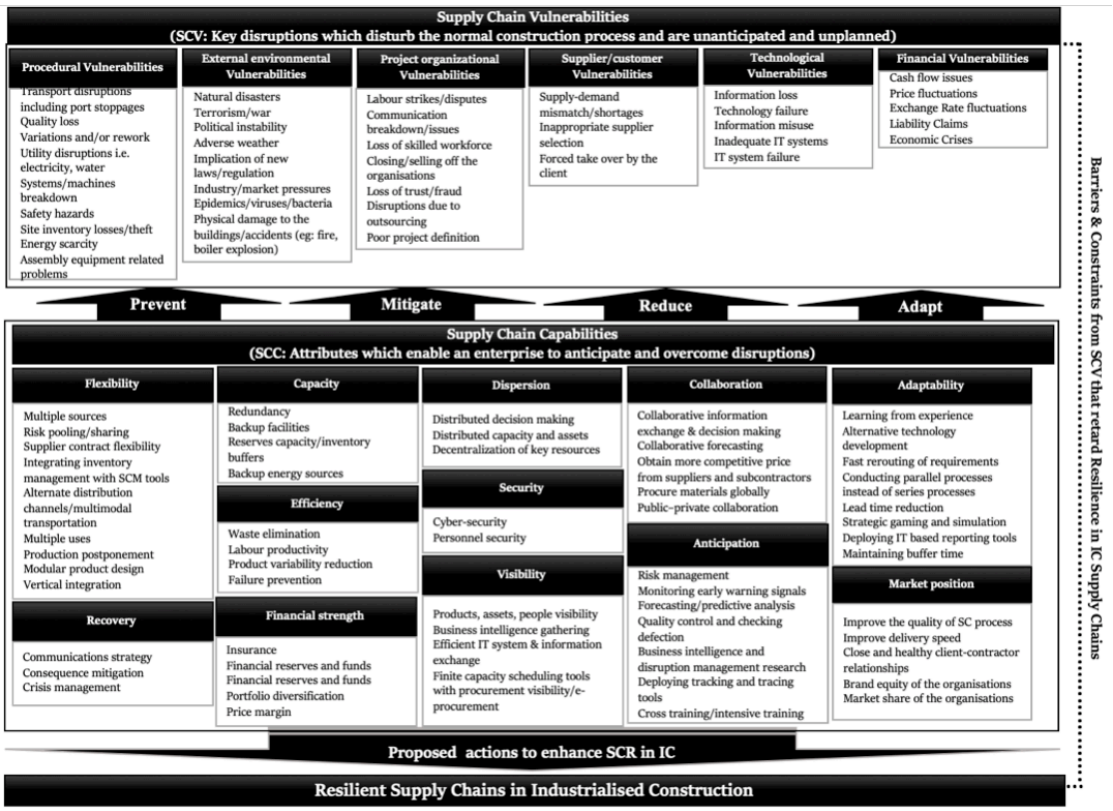


Figure 2: Basic framework for achieving SCR in IC

Procedural vulnerabilities occur from the operation at any node of the supply-distribution-assembly chain. IC SCs are profoundly affected by transport disruptions (Zhai and Huang, 2017). "These are due to traffic jams, customs clearance issues, and damages to the units in transporting" [E1-E6]. "Many of our materials come from Mainland China. And we hold the material at the custom for customs clearance. One or two-days delay is expected there. Sometimes they wait until I call them, to inform me of the delay" [E2]. " Some fittings come from Europe. It will take a longer transportation time. Once there was a delay and, logistic company took 3 months for delivery. So, we need to place orders earlier" [E4]. Further, IC SCs are affected by technical problems with vehicles, too late or too early delivery, and insufficient transportation capacity (Wang *et al.,* 2018). Safety hazards are also a concern in IC assembly (Zhai and Huang, 2017). "Although IC provides a safe working environment, collapsing elements may cause severe hazards which we faced a few years ago" [E3]. "The impact of risks on IC is 'violent' due to shorter schedules,

difficulty in rectifying errors, its inflexibility to design changes during installation, and the prohibitive cost of reworks compared to traditional construction" [E5].

Technological vulnerabilities arise from disruptions of technology changes or failures. Fragmentation of the IC SC results in information losses (Zhai and Huang, 2017). An IC SC is affected by such technological problems (Wang *et al.,* 2018) and hence developed Building Information Modelling (BIM) and Radio Frequency Identification (RFID) enabled IT platforms to achieve real-time visibility and traceability of data in HK (Zhong *et al.,* 2017). "Although we use advanced IT systems, they are not enough to track the logistics failure. Now we are using RFID to trace the process but, they do not capture the whole sequence. Therefore, we are going to implement a BIM-based platform and are working in collaboration with a university research team" [E2-E4].

It is essential to maintain strong financial consistency to withstand financial vulnerabilities in construction SCs (Zainal and Ingirige, 2018). In IC, it is a must to maintain a healthy cash flow to payback prefab manufacturer on time (Kadir *et al.,* 2005); otherwise, the entire SC may collapse. "As a contractor, our products are affected by price fluctuations in HK. Also, we are open to cost overruns due to the construction sequence changes" [E3]. "Anyway, we try to minimise the impact by allowing contingency in the budget" [E2]. "IC reduces time and cost of construction. It makes savings to the clients. Therefore, these projects are financially feasible in HK, and we haven't faced many issues financially" [E1, E5, E6].

Supplier/customer vulnerabilities arise from the client and the supplier who are the critical nodes of a SC. These begin with the supply resource shortages in IC (Zhai and Huang, 2017), accumulate with the supply-demand mismatch and end up in unmet client needs. Especially in IC, insufficient material quantity, poor quality of materials, scarcity of raw parts, and inadequate production resources such as moulds cause the supply-demand mismatch (Wang *et al.,* 2018). "Delaying prefab items cause very negative impacts on our projects, and we need to be careful in selecting the suppliers. Based on the previous project records, we go for the same suppliers. But, if they were repeating the mistakes, we may find another. Generally, we face delays at least once a month" [E2-E4].

Therefore, there is a dire need for 'counteractive' capabilities to successfully withstand these vulnerabilities (Kurniawan and Zailani, 2010). Capabilities including flexibility, capacity, efficiency, visibility, adaptability, anticipation, recovery, dispersion, collaboration, market position, security, and financial strength can prevent, mitigate, reduce or adapt vulnerabilities. "We can have alternative suppliers, flexible agreements to improve SC flexibility" [E3]. "We can integrate the ERP system with SC management to easily detect resource shortages" [E2]. Further, E5 highlighted the need of multifunctional organisations which have vertically integrated SC configuration between logistics, on-site assembly, and manufacturer to improve the SC flexibility. "As we frequently face tower crane breakdowns, low tolerances cause problems in assembly and supply shortages; it is important to have back-up facilities, safety stocks" [E3, E4]. Also, conducting simulation trials in a virtual environment is beneficial in mitigating the risks and rework cost in assembly (Li *et al.,* 2018). "Most of the precast members are heavy and bulky; we need to pay special attention in installation. Workers need to understand the installation programmes fully. If not, accidents may occur" [E2, E3, E5]. This urges adequate fall protection systems during on-site assembly of components and developing training programmes to the workers for enhanced safety (Fard *et al.,* 2017).

"As IC includes vertical transporting of heavy and bulky items, alternative/multimodal transportation is urged to avoid vulnerabilities" [E3, E5]. Integration of BIM and RFID in IC SCs may increase the visibility, collaborative data interoperability and the traceability of the process (Zhong *et al.,* 2017). Integrating BIM with Geo-Information Systems enhance logistical traceability in IC SCs (Irizarry *et al.,* 2013). "Anyway, efficient IT system is vital in IC SCs to link design, prefab, and on-site assembly processes" [E1]. Cost of rearrangement and tardiness penalty can be reduced by maintaining adequate inventory buffers as hedging against SC uncertainty (Zhai *et al.,* 2018). "We use linear programming to optimise inventory buffers in IC to overcome wastage" [E2, E3]. Production, operational and transportation lead time hedging were considered as effective ways to improve SC adaptability in IC (Zhai *et al.,* 2018). "As there are many delays due to transportation, I used to ensure a larger buffer time for me in the schedule, and I make the orders early" [E4]. "Having insurance and contingency allocations, work as a safeguard to bear the uncertainties and losses. It is essential in IC because the construction sequence is fixed and standardised" [E1-E6]. "In HK, most of the public housing developments are prefabricated constructions. There, contractors work together with the public authorities" [E1-E6]. As witnessed, HK IC effectively maintains public-private collaboration as a risk-sharing mechanism to withstand unforeseeable disruptions (Li *et al.,* 2018, Luo *et al.,* 2015).

CONCLUSIONS AND A WAY FORWARD

Findings presented in the current paper identify the vulnerabilities that retard the performance of IC SCs while a suite of counteractive capabilities that can help to withstand these vulnerabilities is also identified. Their juxtaposition is found to be useful and timely to investigate the dynamics of SCR in IC. In this respect, the basic framework to achieve SCR in IC was carefully developed by extracting, consolidating and generalising relevant literature findings and reinforcing them through a preliminary empirical study. The framework would be vital to IC SC stakeholders, not just in terms of identifying vulnerabilities, but also for formulating and/or nurturing adequate capability measures to deal with these vulnerabilities and thereby increase the resilience of IC SCs. This research and development framework will be further explored in the next phase of the current research study through strong empirical justifications and case study validations to formulate an evaluation model to enhance SCR in IC in HK. The outcome would provide pointers and add value to IC SC stakeholders in formulating initiatives to boost SCR, hence enhancing SC performance and productivity in IC.

REFERENCES

Barbosa, F, Woetzel, J, Mischke, J, Ribeirinho, M J, Sridhar, M, Parsons, M, Bertram, N and BROWN, S (2017) *Reinventing Construction: A Route to Higher Productivity*. McKinsey Global Institute.

Bataglin, F S, Viana, D D, Formoso, C T and Bulhões, I R (2017) Application of BIM for supporting decision-making related to logistics in prefabricated building systems, *In*: *Proceedings of the 25th Annual Conference of the International Group for Lean Construction*, Heraklion, Greece, 2017 9-12.

Chang, Y, Li, X, Masanet, E, Zhang, L, Huang, Z and Ries, R (2018) Unlocking the green opportunity for prefabricated buildings and construction in China, *Resources, Conservation and Recycling*, 139, 259-261.

Fard, M M, Terouhid, S A, Kibert, C J and Hakim, H (2017) Safety concerns related to modular/prefabricated building construction, *International Journal of Injury Control and Safety Promotion*, 24, 10-23.

Fiksel, J (2015) *From Risk to Resilience, Resilient by Design*. Cham: Springer.

Gibb, A and Pendlebury, M (2006) *Glossary of Terms*, London: Build offsite: Promoting Construction Offsite

Gibb, A G (1999) *Off-Site Fabrication: Prefabrication, Pre-Assembly and Modularisation*. Chichester: John Wiley and Sons.

Gosling, J, Pero, M, Schoenwitz, M, Towill, D and Cigolini, R (2016) Defining and categorizing modules in building projects: An international perspective, *Journal of Construction Engineering and Managemen*t, 142, 04016062.

Hong, J, Shen, G Q, Li, Z, Zhang, B and Zhang, W (2018) Barriers to promoting prefabricated construction in china: A cost-benefit analysis, *Journal of Cleaner Production*, 172, 649-660.

Irizarry, J, Karan, E P and Jalaei, F (2013) Integrating BIM and GIS to improve the visual monitoring of construction supply chain management, *Automation in Construction*, 31, 241-254.

Jaillon, L and Poon, C S (2009) The evolution of prefabricated residential building systems in Hong Kong: A review of the public and the private sector, *Automation in Construction*, 18, 239-248.

Kadir, M, Lee, W, Jaafar, M, Sapuan, S and Ali, A (2005) Factors affecting construction labour productivity for Malaysian residential projects, *Structural Survey*, 23, 42-54.

Kurniawan, R and Zailani, S (2010) Supply chain vulnerability and mitigation strategy of the manufacturing firms in Indonesia: Manager's perspectives, *International Business Management*, 4, 116-123.

Lawson, R M, Ogden, R G and Bergin, R (2011) Application of modular construction in high-rise buildings, *Journal of Architectural Engineering*, 18, 148-154.

Li, C Z, Hong, J, Xue, F, Shen, G Q, Xu, X and Mok, M K (2016) Schedule risks in prefabrication housing production in Hong Kong: A social network analysis, *Journal of Cleaner Production*, 134, 482-494.

Li, C Z, Xu, X, Shen, G Q, Fan, C, Li, X and Hong, J (2018) A model for simulating schedule risks in prefabrication housing production: A case study of six-day cycle assembly activities in Hong Kong, *Journal of Cleaner Production*, 185(**1**), 366-381.

Luo, L Z, Mao, C, Shen, L Y and Li, Z D (2015) Risk factors affecting practitioners' attitudes toward the implementation of an industrialized building system: A case study from China, *Engineering, Construction and Architectural Management*, 22(**6**), 622-643.

Luo, L, Qiping Shen, G, Xu, G, Liu, Y and Wang, Y (2018) Stakeholder-associated supply chain risks and their interactions in a prefabricated building project in Hong Kong, *Journal of Management in Engineering*, 35(B), 05018015.

Masood, R and Choudhry, R M (2010) Identification of risk factors for construction contracting firms-Encompassing mitigation stance, *In*: *Proceedings of the 2nd International Conference on Construction in Developing Countries*, Cairo, Egypt.

Osei-Kyei, R and Chan, A P (2015) Review of studies on the critical success factors for Public-Private Partnership (PPP) projects from 1990 to 2013, *International Journal of Project Management*, 33, 1335-1346.

Owusu, E K, Chan, A P, Degraft, O.-M, Ameyaw, E E and Robert, O-K (2018) Contemporary review of anti-corruption measures in construction project management, *Project Management Journal*, 50(**10**), 40-56.

Pettit, T J, Croxton, K L and Fiksel, J (2013) Ensuring supply chain resilience: Development and implementation of an assessment tool, *Journal of Business Logistics*, 34, 46-76.

Pettit, T J, Fiksel, J and Croxton, K L J J O B L (2010) Ensuring supply chain resilience: Development of a conceptual framework, *Journal of business logistics*, 31(**1**), 1-21.

Ponomarov, S Y and Holcomb, M C (2009) Understanding the concept of supply chain resilience, *The International Journal of Logistics Management*, 20, 124-143.

Rwamamara, R (2007) Risk assessment and analysis of workload in an industrialised construction process, *Construction Information Quarterly*, 9, 80-85.

Van Der Vegt, G S, Essens, P, Wahlström, M and George, G (2015) Managing risk and resilience, *Academy of Management*, 58(4).

Wang, Z, Hu, H and Gong, J (2018) Simulation based multiple disturbances evaluation in the precast supply chain for improved disturbance prevention, *Journal of Cleaner Production*, 177, 232-244.

Yin, R K (2017) *Case Study Research and Applications: Design and Methods*. London: Sage publications.

Zainal Abidin, N A and Ingirige, B (2018) The dynamics of vulnerabilities and capabilities in improving resilience within Malaysian construction supply chain, Construction Innovation.

Zainal, N A and Ingirige, B (2018) The dynamics of vulnerabilities and capabilities in improving resilience within Malaysian construction supply chain, *Construction Innovation*, 18(**4**), 412-432.

Zavala, A, Nowicki, D and Ramirez-Marquez, J E (2018) Quantitative metrics to analyse supply chain resilience and associated costs, *In*: *Proceedings of the Institution of Mechanical Engineers, Part O: Journal of Risk and Reliability*, 233(**2**), 186-199.

Zhai, Y and Huang, G Q (2017) Operational hedging and coordination in prefabrication construction industry, *Procedia Manufacturing*, 11, 1178-1183.

Zhai, Y, Zhong, R Y and Huang, G Q (2018) Buffer space hedging and coordination in prefabricated construction supply chain management, *International Journal of Production Economics*, 200, 192-206.

Zhai, Y, Zhong, R Y, Li, Z and Huang, G (2017) Production lead-time hedging and coordination in prefabricated construction supply chain management, *International Journal of Production Research*, 55(**14**), 3984-4002.

Zhong, R Y, Peng, Y, Xue, F, Fang, J, Zou, W, Luo, H, Ng, S T, Lu, W, Shen, G Q and Huang, G Q (2017) Prefabricated construction enabled by the Internet-of-Things, *Automation in Construction*, 76, 59-70.

HORIZONTAL INTER-ORGANIZATIONAL COLLABORATION: THE CASE OF THIRD-PARTY LOGISTICS

Andreas Ekeskär[1], Malena Ingemansson Havenvid and Tina Karrbom Gustavsson

Department of Real Estate and Construction Management, KTH Royal Institute of Technology, Teknikringen 10b, SE-10044, Stockholm, Sweden

As a measure to increase performance, improve safety and reduce environmental impact, the use of third-party logistics (TPL) solutions has increased in the construction industry. Other measures are inter-organizational collaborative methods and agreements between different actors. The purpose of this study is to explore how a TPL solution can affect inter-organizational relationships, specifically in the horizontal dimension. Findings are based on a case study of an urban development project with a TPL solution mandatory to use for all construction actors working side by side in parallel and sequential stages. The analysis is based on the industrial network approach, using the ARA-model for identifying and analysing inter-organizational interactions among main contractors. The findings indicate that the contractors do collaborate with each other on both technical and organizational resources, as well as coordinate activities between each other, and that the TPL solution has a vital role in bringing them together and improves collaboration. This nuance the predominant view of the construction industry as being characterized by adversarial relationships and lack of inter-organizational collaboration. It also extends the knowledge of what a TPL solution can contribute with besides improved logistics.

Keywords: horizontal interaction, collaboration, industrial network approach

INTRODUCTION

Several measures have been taken in the construction industry to achieve a more efficient production as well as improving safety and reducing environmental impact. One such measure is supply chain management (SCM) and the implementation of third-party logistics (TPL) solutions (Ekeskär and Rudberg 2016; Sundquist *et al.,* 2018; Janné and Fredriksson 2019). Other measures are the efforts on collaborative methods and agreements between clients and contractors (Bygballe *et al.,* 2010). These examples address the importance of inter-organizational relationships for developing the construction industry, something which is acknowledged in construction management literature (e.g. Tennant and Fernie 2014; Bygballe and Swärd 2019).

Most studies on TPL solutions do, however, focus on logistics, SCM principles and productivity performance (cf. Lindén and Josephson 2013; Ekeskär and Rudberg

[1] andreas.ekeskar@abe.kth.se

Ekeskär, A, Havenvid, M I and Gustavsson, T K (2019) Horizontal Inter-Organizational Collaboration: The Case of Third-Party Logistics *In:* Gorse, C and Neilson, C J (Eds) *Proceedings of the 35th Annual ARCOM Conference,* 2-4 September 2019, Leeds, UK, Association of Researchers in Construction Management, 821-830.

2016; Sundquist *et al.,* 2018; Janné and Fredriksson 2019) and not on inter-organizational relations. This is despite that a TPL provider may induce collaboration both vertically and horizontally in situations when there are no formal contracts. For the purpose of exploring how a TPL solution affect inter-organizational relationships specifically in the horizontal dimension, we explore interactional patterns that take place between main contractors in a multi-project context. When these contractors, that may be considered competitors, initiate interaction it can be interpreted as a mechanism for operating efficiently in multi-project contexts. The following research questions guide the study:

- What kinds of inter-organizational collaborations exist between main contractors in an urban development project?
- What role does a TPL solution have in stimulating inter-organizational collaboration?

For this purpose, we use the industrial network approach, or IMP perspective (Industrial Marketing and Purchasing), which specializes in analysing inter-organizational interaction (Håkansson and Snehota 1995; Håkansson *et al.,* 2009). By using the ARA-model (Activities-Resources-Actors), we have been able to detail the content of horizontal inter-organizational relationships. Based on the findings, we discuss what role a TPL solution can play for this type of inter-organizational collaboration and we provide new insights on the nature of inter-organizational relationships in the construction industry.

The empirical case covers a TPL solution implemented in an urban development project in Sweden called Stockholm Royal Seaport. An urban development project can be considered as an inter-organizational multi-project context (Engwall and Jerbrant 2003), which in each stage includes a multitude of parallel construction projects involving a multitude of developers, contractors and sub-contractors, and that each stage can be considered a multi-project. Consequently, the need for coordination of both resources and activities within, and across, construction projects in the same stage will prompt interaction among these actors.

LITERATURE OVERVIEW

Third-Party Logistics in Construction

Construction activities take place by temporary organizations at unique sites. This induces temporary supply chains and the need of project specific logistics setups (Dubois and Gadde 2002). Traditionally, the contractors managed the handling of materials, but since a decade dedicated construction logistics solution operated by TPL providers challenge this setup (Ekeskär and Rudberg 2016). TPL solutions are often mandatory to use and can be initiated by a developer (Ekeskär and Rudberg 2016; Sundquist *et al.,* 2018) or by a municipality (Janné and Fredriksson 2019). Studies indicate that contractors are reluctant to work with TPL solutions, due to cost (Ekeskär and Rudberg 2016). However, other studies indicate that TPL solutions decrease costs (Lindén and Josephson 2013), improve performance (Ekeskär and Rudberg 2016; Sundquist *et al.,* 2018), increase consolidation and reduce the number of deliveries (Janné and Fredriksson 2019; Dubois *et al.,* 2019).

Inter-Organizational Relationships in Construction

The development of inter-organizational relationships is related to the temporary character and the high level of specialization across a great number of actors. Organizing by projects lead to short-term relationships in unique constellations rather

than long-term relationships in established networks (Bakker 2010). However, it is primarily the adversarial nature of these short-term relationships and the consequences hereof that has raised the critique of construction lagging behind other industries in terms of productivity and innovativeness (Miozzo and Dewick 2004). One example is the way competitive tendering is practiced in the supply chain (Bygballe *et al.,* 2010). In this regard, although found challenging, partnering has been presented and studied as a possible solution towards more collaborative work practices and new ways of interacting within and across projects (Bresnen 2010; Bygballe and Swärd 2019). Also, it has been indicated that when possible and beneficial, construction firms and professionals can actively create "bridges" between organizations, between projects and the resources and activities they engage in over time (Havenvid *et al.,* 2019). For instance, in terms of the materials and technologies they use within and across projects (Bengtson and Håkansson 2007; Havenvid *et al.,* 2016b), how they learn within and across projects (Håkansson *et al.,* 1999; Håkansson and Ingemansson 2011), and how they develop new solutions within and across projects (Havenvid *et al.,* 2016a; Havenvid *et al.,* 2016b). While these studies provide a more nuanced picture of how construction actors operate and interact, further studies are needed in order to understand the forms of interaction that these firms engage in and what role interaction plays in this specific industry context. For the present study, we identify the industrial network approach suitable for further detailing and analysing how and why construction firms engage in interaction as a result of using a TPL provider. This approach has been used in previous studies on TPL in construction (Sundquist *et al.,* 2018).

THEORETICAL FRAMEWORK

Industrial Network Approach

The industrial network approach emphasizes inter-organizational relationships between organizations; how they relate and interact with each other and as a consequence, how they adapt in relation to each other (Håkansson and Snehota 1995; Håkansson *et al.,* 2009). This approach sprung from studies of long-term business relationships and has as a consequence mostly been applied when studying these kinds of more stable relationships in industry sectors such as the automotive industry (e.g. Dubois and Fredriksson 2008). However, several studies have applied the industrial network approach in the construction industry and interactions in the project-based context studying organizing and productivity (Dubois and Gadde 2002), innovation (Dubois and Gadde 2002; Bygballe and Ingemansson 2014; Havenvid *et al.,* 2016a), fragmentation (Havenvid *et al.,* 2016b) and logistics (Sundquist *et al.,* 2018; Dubois *et al.,* 2019). While the project-based nature of the construction industry creates a loosely coupled system over time (Dubois and Gadde 2002), several studies show that there are active efforts of interconnecting both organizations and projects over time (e.g. Havenvid *et al.,* 2019).

One of the models developed for analysing the content of business relationships is the ARA model which takes its stance in three different but interrelated dimensions of how organizations interact: Actors, resources and activities. Actors can be understood as companies, organizations or individuals representing technical or organizational resources, such as materials, machines and competence. These resources are used in activities such as planning, and production performed by actors. The model reveals how these three dimensions are related to each other. Actors can combine resources (forming ties) or link activities (forming links) across firm boundaries in order to

create new combinations that in turn increase the overall efficiency of both inter-firm and intra-firm operations (Håkansson and Snehota 1995). In such interaction processes, actors form social sentiments towards each other, superficially or more profound depending on the nature of the interaction. As such, actors form specific bonds. From the standpoint that organizations need to cope with and build interdependences to run and develop their operations, interaction is an essential part of the industrial network approach; no actor can control all activities and resources but are dependent on other actors (Håkansson *et al.,* 2009; Gadde *et al.,* 2003; Håkansson and Snehota 1995).

RESEARCH DESIGN

Research Approach

A case study approach according to the principles described by Yin (2014) have been performed. The case study covers a particular stage in the urban development project Stockholm Royal Seaport (SRS) that utilized a TPL provider. A case study approach is appropriate when striving to understand interactions in complex organizational contexts (Flyvbjerg 2006) and is also a recommended approach when studying inter-organizational relationships in industrial networks (Easton 2010). The primary data includes semi-structured interviews and participatory observations between November 2018 and June 2019. The ARA model was used to formulate interview questions specifically in tracing what ties, links, and/or bonds that arose between contractors. A total of ten semi-structured interviews with managers from contractors (four interviews) and representatives from the TPL provider (six interviews), and 21 sequential participatory observations of coordination meetings with representatives from the contractors, the TPL provider and the city, are included. Additional data sources are informal observations and conversations on the construction site, documents and reports. The empirics is analysed using the ARA-model described by Håkansson and Snehota (1995).

Case Description

SRS is an ongoing urban development project in Stockholm, Sweden. The city of Stockholm is developing 12,000 apartments and 35,000 workplaces between 2011 and 2030. In each stage of SRS there are multiple construction projects, with typically five to ten different developers and numerous contractors and subcontractors in each stage. This case study focuses on the stage called Brofästet, which includes nine housing developments and seven different main contractors (some developers use the same main contractor, although with different site organizations).

Early on in the planning of SRS the city of Stockholm decided to use a dedicated logistics solution called construction logistics centre (CLC) operated by a public procured TPL provider. The aim is to reduce impact on third parties and increase environmental sustainability of urban development projects. The CLC is mandatory to use for all construction actors in SRS and is setup with a terminal for short term material storage; no construction materials are allowed to be stored around the building. When contractors need material, they make a request from the CLC who deliver it to the contractors for a symbolic fee. Certain deliveries can be transferred directly to the construction sites but have to meet certain regulations and needs to be coordinated with the CLC. The CLC is also responsible for collection of waste materials for recycling, gates and fences, snow clearing, surveillance, etc. There are

also some additional services such as providing certain machines, logistics consultants, inward transport of materials, etc.

The CLC has five stage coordinators responsible for coordinating the activities within each stage of SRS. In order to do so the coordinators arrange weekly as well as monthly coordination meetings mandatory for the contractors to attend. The meetings allow the contractors to coordinate and inform each other about upcoming construction activities such as large deliveries or the use of mobile cranes obstructing road access within the stage. The meetings have also become a forum for all contractors to regularly meet and to discuss both formal and informal matters.

FINDINGS

Despite belonging to different firms and being contracted by different developers the contractors in the same stage do not seem to view each other as competitors. On the contrary, they seek help from each other, and they provide each other support in terms of information and experience in situations, for example on what subcontractor to use and not. They also actively coordinate their construction activities and their scheduled deliveries in a way to minimize disturbances for each other. Another example of their interaction is the sharing of resources such as subcontractors, cranes and storage spaces.

"If I want to book a mobile crane, that might block [Contractor 6] further away. Then it is my role to contact him and ask him 'next week on Monday, do you have something big that needs to pass, or can we set it up on Monday for half a day?' Then we discuss it; 'it is better if we do it on Tuesday' or 'we can move our delivery so that we take it straight in the morning.'" - Site manager of Contractor 4

The contractors are not the only actor initiating interaction among actors; the city, the developers and the CLC also initiate interaction. For example, the city has procured the CLC and support staff in order to act as integrators, competence pool and service support for a smooth and efficient construction of SRS. The developers have also initiated interaction, for example by planning for a joint main contractor in two different, but neighbouring, projects. Also, the developers have arranged for and procured their joint contractors for joint facilities. The CLC as such has also initiated interaction by arranging meetings and taking daily site tours, enabling actors to link projects together. Hence, the CLC has become a widely appreciated resource for coordinating the activities between the different construction projects and contributed to an overall feeling among the main contractors of being part of the same multi-project context.

"Sometimes I do not believe the content of the coordination meetings necessarily is the most important thing, but to have a forum where everyone meets and says hello. It becomes a little easier to pick up the phone when you need something or if something hassles. So, I believe they have been very important to create a team spirit within the stage." - Site manager of Contractor 2a

For the contractors the CLC represents a combination of resources with ties to the city, all developers, main contractors as well as subcontractors, working in the same stage. The CLC represents a resource that can be utilized in several different ways, both technical (e.g. as short-term storage of materials, machine pool, etc.) and organizational (e.g. for coordination of construction activities and incoming delivers, coordination meetings, service activities, etc.).

Table 1: Inter and intra-organizational effects across projects among the main contractors

Actors bonds	Resource ties	Activity links
Contractor 1a - Contractor 1b	Sharing subcontractor	Coordination meetings
(intra-organizational)	Sharing of construction workers	Collaborate about time plans
	Sharing crane	Joint procurement of construction materials
		Joint/coordinated procurement of subcontractor for civil works
Contractor 1a - Contractor 2a	Sharing subcontractor	Coordination meetings
		Coordinating and transfer of responsibility for construction work environment of shared courtyard
		Joint/coordinated procurement of subcontractor for civil works
Contractor 1b - Contractor 2a	Sharing crane	Coordination meetings.
	Sharing subcontractor	Joint/coordinated procurement of subcontractor for civil works
Contractor 2a - Contractor 2b	Sharing of construction workers	Sharing experience on technical solutions
(intra-organizational)	Sharing construction site office	
	Procured same subcontractor	
Contractor 3 - Contractor 2a	Sharing boom lift	Coordinating construction activities
Contractor 3 - Contractor 1a		Coordinating construction works
Contractor 3 - Contractor 5		Coordinating construction activities
		Coordination meetings
Contractor 3 - Contractor 6		Coordination meetings
Contractor 3 - Contractor 2b		Coordination meetings
Contractor 4 - Contractor 6	Sharing subcontractor	Performing minor construction works
		Coordination meetings
Contractor 4 - Contractor 3		Coordinating construction works
		Coordination meetings
Contractor 4 - Contractor 2b	Sharing subcontractor	Coordination meetings of construction of shared garage
Contractor 4 - Contractor 5		Coordination meetings
Contractor 5 - Contractor 6		Coordination meetings
Contractor 5 - Contractor 7		Coordinating construction activities
Contractor 6 - Contractor 2b	Sharing subcontractor	Coordination meetings of construction of shared garage
Contractor 7 - Contractor 3	Taking over lease of construction site office	Coordinating construction activities

Even though the CLC is mandatory to use, the contractors do not perceive the CLC to be forced upon them, but rather as a project precondition and in some *respects*, they view it as a necessity in multi-project contexts. In Table 1 both inter- and intra-organizational as well as inter-project effects of interactions are listed for the three ARA-dimensions (actors, resources and activities).

Bonds, Ties and Links

The resource ties include both technical (e.g. machines) and organizational (e.g. subcontractors) resources, and in certain cases (e.g. joint procurement of subcontractor) also involve interaction on several organizational levels between the contractors (procurement division, site managers and supervisors). This means that benefits of collaboration involve different kinds of resources as well as functions within the actors' organizations.

The activity links tend to be about coordination of different resources connected to either shared production activities (e.g. shared garage or shared courtyard) or the use of shared space or transports, exemplified by e.g. coordination meetings in Table 1. These coordination meetings are initiated by the contractors in order to coordinate specific activities between the involved projects and are not to be confused with the mandatory coordination meetings held by the CLC that involved all main contractors from all developments. Location and timing thus seem to be central aspects for both resource ties and activity links; it is easier for contractors to collaborate if the projects are located nearby. Space is also an important aspect of collaboration; generally, the coordination or collaboration occurred when it involved construction activities outside the buildings such as courtyards or deliveries that potentially blocks other construction projects. The examples of collaboration that has gone furthest and involved actors on different levels within both contractors' organizations are examples of that. Furthermore, the utilization of established resources such as subcontractors or cranes is of essence; the contractors perceive benefits of using each other's access to and experience of specific resources.

According to the contractors, seeking collaboration with other contractors in other projects is not the normal thing to do. There are no clear incentives and first focus is often to collaborate within their own project with their own subcontractors (vertically). Therefore, much of the common way of cooperating is based on a reactive mode, i.e. they adapt to others. However, when trying to be proactive it is usually in favour of themselves. An example is when Contractor 2a needed an additional crane and contacted Contractor 1b early on in order to use their crane. The coordination meetings held by the CLC were very important for this type of interactions by introducing the contractors to each other and learn about other projects' resources and activities. Another example is when Contractor 5 who needed additional barracks for their site office and learned that Contractor 3 was about to return some of theirs to the renter in a few days; Contractor 5 asked Contractor 3 if they could take over the lease of the barracks, but that was not possible due to the short time frame. However, Contractor 5 had not attended previous coordination meetings and had therefore missed this information and therefore missed out on the opportunity to act upon it.

DISCUSSION

The studied case is a special case; there are several contractors simultaneously working tightly within a limited shared space, contracted by different developers. In this context this means that they have context specific mandatory regulations on how to plan and execute activities with regard to for example a dedicated construction logistics solution. However, urbanization is a global trend and urban development projects will develop further.

Collaboration in the multi-project context

The contractor's express unfamiliarity with the context dependent regulations, in relation to their normal ways of working. Traditionally, they focus on their specific projects but here they have to include also other projects in their planning and execution. However, working in a multi-project context characterized by several simultaneously ongoing construction projects within the tight space of the stage boundaries was also considered unusual by the contractors. Based on these preconditions it became a necessity to collaborate in order to work efficiently. This collaboration was both inter-organizational as well as inter-project. The TPL provider also had a large role in stimulating collaboration by introducing projects and actors to each other in the mandatory coordination meetings.

As Table 1 shows, there are several instances of collaboration between a number of different contractors, even though it remains on a rather basic level. Due to their internal policies and regulations; as well as framework agreements with e.g. suppliers, deeper collaboration is considered difficult by the contractors. When for instance joint procurement occurred, it was either intra-organizational or it involved the sharing of space.

Deep collaboration often requires long-term perspectives. When compared with partnering, long-term perspectives such as strategic partnering extends beyond the specific project (Bygballe *et al.,* 2010). However, the interviews indicate that also separate projects are viewed as long-term by the contractors. Consequently, contractors have another view on what long-term perspective is; for them working two to three years on a project is working long-term.

In the project management literature projects are said to be constituted by four main concepts - time, team, task and context (Bakker 2010). Time in the meaning that they are temporary; team in the sense that the project needs to acquire the necessary members in order to fulfil the task, e.g. construct a building; context refers to the project and its permanent environment. In this study it is found that location is a dimension that affect how the actors in a project plan and perform their work. The contractors are dependent on their location in order to perform certain tasks and to which team members they collaborate with.

CLC as a combination of resources

The study focuses on the contractors and how they interact; for them the CLC is a combination of resources providing both technical and organizational resources. This is in line with the conclusion in Ekeskär and Rudberg (2016) that a CLC is a service function to the contractors, and in a wider perspective also to the urban development project and has therefore not a purpose of its own. This study shows that the CLC does more than coordinate the contractors incoming deliveries and other logistics related issues (Janné and Fredriksson 2019). It also positively influences coordination of activities between the contractors. The contractors express that if the CLC would not have existed, the contractors probably would have had coordination meetings of their own, but they would have been affected by the contractors' adversarial relationships. In fact, the contractors did have several coordination meetings of their own, however they focused on issues concerning only two or a small number of actors and projects. A CLC can therefore be a mitigating factor in overcoming adversarial relationships among contractors, and also bring different projects together as a team in the multi-project context.

CONCLUSIONS

The purpose is to explore how a TPL solution affects inter-organizational relationships in the horizontal dimension. Given these factors and findings from previous research, there should be a lot of controversies and conflicts due to fragmentation and adversarial relationships (cf. Miozzo and Dewick 2004). However, the findings indicate that the contractors do collaborate with each other regarding both technical and organizational resources, as well as coordinate activities between each other; within the timeframe of the projects, they develop bonds, ties and links. Some collaboration goes deeper than other, even though much of the collaboration is on a rather basic level.

Deep collaboration is found in long-term relationships. However, in this case study the contractors view their separate projects as long-term, a view which includes the inter-organizational relationships with other actors. This calls for a broader definition and a need to contextualize what long-term perspective means, especially in a loosely coupled network (Dubois and Gadde 2002) such as the construction industry. In addition, the interactions found nuance the predominant view of the construction industry as just adversarial.

Furthermore, this study extends the notion of what a dedicated TPL solution can contribute with besides improving logistics. By holding coordination meetings and having employed personnel responsible of coordinating construction activities, it can improve collaboration between actors in a multi-project context and thereby mitigate adversarial relationships. A TPL solution can therefore have an important role to fulfil by creating the team in the multi-project context.

This is an ongoing case study, the findings and the conclusions should be seen as tentative, however indicating the need for further studies of horizontal inter-organizational relationships in multi-project contexts.

REFERENCES

Bakker, R M (2010) Taking stock of temporary organizational forms: A systematic review and research agenda, *International Journal of Management Reviews*, 12(**4**), 466-86.

Bengtson, A and Håkansson, H (2007) Introducing old knowledge in an established user context: How to use wood in the construction industry, *In:* H Håkansson (Ed.) *Knowledge and Innovation in Business and Industry: the Importance of Using Others*. Abingdon: Routledge Taylor and Francis Group, 54-78.

Bresnen, M (2010) Keeping it real? Constituting partnering through boundary objects, *Construction Management and Economics*, 28(**6**), 615-28.

Bygballe, L E, Jahre, M and Swärd, A (2010) Partnering relationships in construction: A literature review, *Journal of Purchasing and Supply Management*, 16(**4**), 239-53.

Bygballe, L E and Ingemansson, M (2014) The logic of innovation in construction, *Industrial Marketing Management*, 43(**3**), 512-24.

Bygballe, L E and Swärd, A (2019) Collaborative project delivery models and the role of routines in institutionalizing partnering, *Project Management Journal*, 50(**2**), 161-76.

Dubois, A and Gadde, L-E (2002) The construction industry as a loosely coupled system: Implications for productivity and innovation, *Construction Management and Economics*, 20(**7**), 621-31.

Dubois, A and Fredriksson, P (2008) Cooperating and competing in supply networks: Making sense of a triadic sourcing strategy, *Journal of Purchasing and Supply Management*, 14(**3**), 170-9.

Dubois, A, Hulthen, K and Sundquist, V (2019) Organising logistics and transport activities in construction, *International Journal of Logistics Management*, 30(**2**), 620-40.

Easton, G (2010) Critical realism in case study research, *Industrial Marketing Management*, 39(**1**), 118-28.

Ekeskär, A and Rudberg, M (2016) Third-party logistics in construction: The case of a large hospital project, *Construction Management and Economics*, 34(**3**), 174-91.

Engwall, M and Jerbrant, A (2003) The resource allocation syndrome: The prime challenge of multi-project management? *International Journal of Project Management*, 21(**6**), 403-9.

Flyvbjerg, B (2006) Five misunderstandings about case-study research, *Qualitative Inquiry*, 12(**2**), 219-45.

Gadde, L-E, Huemer, L and Håkansson, H (2003) Strategizing in industrial networks, *Industrial Marketing Management*, 32(**5**), 357-64.

Havenvid, M I, Hulthén, K, Linné, Å and Sundquist, V (2016a) Renewal in construction projects: Tracing effects of client requirements, *Construction Management and Economics*, 34(**11**), 790-807.

Havenvid, M I, Håkansson, H and Linné, Å (2016b) Managing renewal in fragmented business networks, *Imp Journal*, 10(**1**), 81-106.

Havenvid, M I, Bygballe, L E and Håkansson, H (2019) Innovation among project islands: A question of handling interdependencies through bridging, *In:* M I Havenvid, Å Linné, L E Bygballe, and C Harty (Eds.) *The Connectivity of Innovation in the Construction Industry*. London: Routledge.

Håkansson, H and Snehota, I (1995) *Developing Relationships in Business Networks*. London: Routledge.

Håkansson, H, Havila, V and Pedersen, A-C (1999) Learning in networks, *Industrial Marketing Management*, 28(**5**), 443-52.

Håkansson, H, Ford, D, Gadde, L-E, Snehota, I and Waluszewski, A (2009) *Business in Networks*. Chichester: John Wiley and Sons.

Håkansson, H and Ingemansson, M (2011) Construction companies and how they acquire knowledge through business interaction, *Imp Journal*, 5(**2**), 67-78.

Janné, M and Fredriksson, A (2019) Construction logistics governing guidelines in urban development projects, *Construction Innovation*, 19(**1**), 89-109.

Lindén, S and Josephson, P E (2013) In-housing or out-sourcing on-site materials handling in housing? *Journal of Engineering, Design and Technology*, 11(**1**), 90-106.

Miozzo, M and Dewick, P (2004) Networks and innovation in European construction: Benefits from inter-organisational cooperation in a fragmented industry, *International Journal of Technology Management*, 27(**1**), 68-92.

Sundquist, V, Gadde, L-E and Hulthén, K (2018) Reorganizing construction logistics for improved performance, *Construction Management and Economics*, 36(**1**), 49-65.

Tennant, S and Fernie, S (2014) Theory to practice: A typology of supply chain management in construction, *International Journal of Construction Management*, 14(**1**), 72-87.

Yin, R K (2014) *Case Study Research Design and Methods 5th Edition*. Thousand Oaks, California: SAGE Publications, Inc.

SUSTAINABLE RENOVATION

THE INTEGRATION OF RETROFIT PRACTICE WITHIN SOCIAL HOUSING

Dayna Rodger[1], Nicola Callaghan and Craig Thomson

School of Computing, Engineering and Built Environment, Glasgow Caledonian University, Cowcaddens Road, Glasgow, G4 0BA, UK

Efficiently and sustainably addressing the social and economic demands arising for the world's ageing population is a major global challenge. An ageing population has significant implications for public policy such as housing, health and welfare, therefore requiring holistic integration across a range of service providers. Through the lens of institutional theory, this study seeks to explore the levels of integrated retrofit practice within social housing under a constructivist approach. Following a scoping study of 24 key stakeholder interviews across Scotland, this paper presents the second phase of research undertaken to evaluate collaboration and knowledge sharing within social housing retrofit practice for the improved wellbeing of an ageing population. Presented are the findings of a single case study of a social housing provider, through analysis of nine hierarchical stakeholder interviews determining the success and failures to create integrated retrofit practice. The hierarchical structures with silo-based application have created the belief that each sector are separate entities with separate agendas, however these are interlinking, with a much broader social and economic impact. Therefore, there is a need to break through these intrinsic neoliberal barriers created, with defined boundaries of policy and budgets, to create a collaborative approach to retrofit practice.

Keywords: Ageing population, institutional theory, retrofit and social housing

INTRODUCTION

Whilst environmental health is closely related to and affected by socioeconomic status, public health research has given less attention to the complex relationship between housing and health within retrofit practice and the implications of this upon policy improvement (Van Hees *et al.,* 2017). Housing as part of health improvements is often implicit within policy, however, unlike health service interventions, the main aim of housing enhancements are not improvements made to health. A need is emerging to examine the nexus between the energy, health and housing sectors to determine the practical implementation of the 'Ageing in Place' agenda through collaboration and knowledge share within housing improvements. A holistic, multidimensional approach is required to account for the social, economic, environmental and institutional aspects of sustainability, and must not focus solely upon the consumption of resources. Considering the fundamental necessity of the built environment to human existence and societal development (Smiley *et al.,* 2014), there is a need to examine how the mechanisms commonly used to establish and develop collaboration and knowledge share may enable or hinder joint activity and interaction within, and across, different sectors (Bresnen, 2010). This paper presents

[1] drodge200@caledonian.ac.uk

Rodger, D, Callaghan, N and Thomson, C (2019) The Integration of Retrofit Practice within Social Housing *In:* Gorse, C and Neilson, C J (Eds) *Proceedings of the 35th Annual ARCOM Conference,* 2-4 September 2019, Leeds, UK, Association of Researchers in Construction Management, 832-841.

the second phase of research undertaken to evaluate the success of collaborative efforts within social housing to perform retrofit practice for the improved wellbeing of an ageing population (Rodger *et al.,* 2018). Presented are the findings of a single in-depth case study of a social housing provider, through analysis of nine hierarchical stakeholder interviews determining the successes and failures to create integrated retrofit practice.

LITERATURE REVIEW

Theoretical framework

Institutional theory is vital in explaining how organisations are influenced by their environments (DiMaggio and Powell, 1983). Utilising the concepts of isomorphism (Hawley, 1968) it explains the constraining processes that force organisations to resemble one another. Thus, developing structural rules and procedures which do not necessarily improve efficiency, but gain the appearance of being legitimate to external parties (Abdul-Aziz *et al.,* 2010). Within this research, institutional theory provides a lens to analyse decision-making and examine the broader implications of power struggles enabling or preventing collaboration and knowledge share within retrofit practice.

The importance of housing and retrofitting

A major global challenge is efficiently and sustainably addressing the social and economic demands arising from the global growing ageing population. An ageing population has significant implications for public policy encompassing health, housing and welfare amongst others. Both housing and health policy promote the idea of 'home' as the best place to grow old, with the option of moving to specialist accommodation to be avoided for as long as possible. Ageing in place, or "*the ability to live in one's own home for as long as confidently and comfortably possible*" is the ability to be self-reliant at home for as long as it is viable (Shelter, 2007). As people age, declining mobility and illness can lead to their residence becoming unsuitable without support or adaptation, often forcing individuals to move into specialist accommodation (Van Hees *et al.,* 2017). However, another major challenge is the prevention of the ageing and deterioration of the housing stock. Energy efficiency improvements made to buildings is considered to be one of the most effective measures to reduce carbon emissions, especially in those which are characterised by poor energy performance (Saidur, 2009). Reducing the exposure of older residents to cold housing and providing access to affordable warmth is a key priority in defeating health issues associated with poor housing conditions. Therefore, to achieve sustainability, there must be an understanding that human health and the environment are both inextricably linked.

The need for integration within retrofit practice

The term retrofit is used to describe a range of activities involved in the repair, improvement and maintenance of buildings, incorporating innovations which directly shape energy use or influence user behaviour (Buser and Carlsson, 2016). However, in the context of this research it is used to describe all alternations to the internal or external building, including ramps and wet floor showers. With an ageing population, great challenges are presented due to increasing acute and long-term requirements. However, many social care and health experts have confessed the lack of linkages within, and understanding of, housing practice which has meant older people's needs have not been optimally considered or prioritised (Zhang *et al.,* 2018). Energy

efficiency adaptations affect and are affected by a wide range of policy domains including housing, construction, environmental, health and fiscal policy. However, across these various levels of policy and decision-making, there are diverse agendas and actors with different needs, methods and priorities, creating substantial barriers. It has been suggested that collaborative or partnership working brings a multitude of perceived benefits to all parties involved (Bresnen, 2010) including increased productivity, reduced costs, time and a reduction within industry fragmentation (Smiley *et al.,* 2014). Nonetheless, despite enthusiasm from policy makers, this new way of working has yet to materialise (Bresnen, 2010). It is acknowledged that there are key institutional and political restrictions shaping partnership working within and across organisations, such as hierarchies, power, inequality and vested interests, particularly within capitalist societies (Smiley *et al.,* 2014). However, there is a need for a holistic retrofit system which takes account of the varying needs of older people, creating a practice focused on all aspects of the resident's domestic environment: of habitability, safety and accessibility, especially for older people. Thus, aligning national housing, energy and health policy into a cost-efficient practice with wider fiscal and societal benefits such as reduced pressure on primary health care.

Neoliberalism within public services

Framed by a sustained period of austerity, as a consequence of the 2007/8 financial crisis, the UK and much of Europe have experienced public spending cuts which were ideologically placed upon the most disadvantaged within society (Suttor, 2011). However, the restructuring and reduced investment of the public sector began in the 1970's with the emergence of New Public Management (NPM); driven by the belief that the public sector was inherently inefficient, monopolistic and a drain on public financing (Hood, 1991). This restructuring of social housing and wider public services gave rise to a fragmented system, with privatisation, including sub-contracting work and competitive bidding, leading to institutional, organisation and managerial changes (Mullins *et al.,* 2001). Furthermore, government has not protected social housing, with all state and not-for-profit housing providers adhering to neoliberal practices such as competition, hierarchy and public/private partnerships (Jacobs *et al.,* 2013). The rationale behind these modernisation initiatives is constructing the appearance that services can improve during a time of reduced investment and resources (Jacobs *et al.,* 2013). Therefore, these traditions of care are threatened by the growing commercialisation of state services, centred upon investment and asset management, rather than the care (Power and Bergan, 2018). However, partnership working between different areas of the public, private and voluntary sector is seen as a way of potentially improving services, especially where there is commonality of interest and a history of failing to coordinate services effectively (Rummery, 2009). With the collective agendas formed to support an ageing population, there is a need for social housing, the energy sector and health and social care providers to work together to support adaptation of the housing stock and ensure its long-term asset management (Boyle and Thomson, 2016).

Institutional structures

The 'rolling back of the state' within UK government policies is perceived to have created an irreversible reduction within the role of public sector institutions. Furthermore, the introduction of market competitiveness through the emergence of NPM exacerbated the government's inability to direct and develop multi-agency arrangements, focusing on target driven, rather than cooperative progress (Hood,

1991). This concept of strategic management and modernisation have become key to organisational effectiveness; emphasising the importance upon structures and its hierarchically regulated public sector (Mullins *et al.,* 2001). Likewise, within this context policy evaluation can be understood to be a means of providing evidence to legitimise policies and political commitments, rather than completing the policy cycle and providing feedback to improve policy design (Sanderson, 2002; Rasmussen *et al.,* 2017). Thereafter, this process leads to the marketisation of functions, traditionally held within public sector, transforming policy-making away from joint programmes led by an active governance (Rasmussen *et al.,* 2017). This can be represented within social housing's hierarchy and coordinating systems which are based on the principles of command and control, creating clear specification of roles, responsibilities and functions, with formalised communication and reporting procedures (Mullins *et al.,* 2001). Thereafter tying in with the increased influence of managerialism and modernisation which is linked with privatisation, marketisation and contracting out policies; creating the appearance of success whilst not always selecting the most efficient processes (Mullins *et al.,* 2001). Thus, institutional theory is utilised in analysing the influence of hierarchical structures and the normalisation of neoliberal concepts within the practical implementation of an integrated retrofit practice in line with a global agenda of ageing in place.

METHODOLOGY

The aim of this study is to explore the levels of integrated retrofit practice within social housing for the improved wellbeing of an ageing population under a constructivist approach. This is the second phase of research following 24 in-depth interviews across housing, energy, health, and governance to determine the wider issues felt within these sectors, creating the framework which revealed institutional theory as a lens for future enquiry. This research seeks to develop an understanding of collaboration and knowledge share within retrofit practice, through an in-depth single case study of a social housing provider (SHP) within Scotland, UK.

Epistemology

To ensure a strong research design, it is vital to choose a research paradigm compatible with personal beliefs about the nature of reality. By subjecting such beliefs to an ontological interrogation aided within the decision-making process of the epistemological and methodological variables available it was possible to determine the most appropriate methodology (Mills *et al.,* 2006). We are all influenced by our history and cultural context, which shapes our view of the world and the meaning of truth. Therefore, assuming a relativist ontological position; the world consists of multiple individual realities which are influenced by context (Mills *et al.,* 2006). Epistemologically, constructivism is a research paradigm that denies the existence of an objective reality, asserting instead that realities are social constructions of the mind, and there are many that exist (Hayes and Oppenheim, 1997). By taking a constructivist perspective to data analysis in this research, the data is seen through the perspective that meaning and experience are socially produced and reproduced, rather than existing within the individuals. Furthermore, constructivism permits an emphasis on the subjective interrelationship between the researcher and participant, and co-constructing of meaning (Hayes and Oppenheim, 1997) which is important in this context given the need to engage with actors who shape decisions. This enables the researchers to be part of the research and enabling our values to be acknowledged by themselves as an inevitable aspect of the analysis and discussion.

Approach

Within this research, an exploratory single case study approach was adopted. By undertaking this approach, it enables the researcher to closely examine the data within a specific context, investigating contemporary real-life phenomenon through contextual analysis of an environment (Yin, 2017). However, the limitations of a single case study are acknowledged, with multiple case studies creating more robust insights in a wider context (Yin, 2017). However, theoretical explanations of the data observed may be applicable across similar state housing providers.

Methods

Purposeful sampling was undertaken, by interviewing a wide range of stakeholders, at multiple levels, it leads to richer, more reliable emergent theory (Eisenhardt, 1989). Interviews lasted between 42-93 minutes. In total 13 stakeholders were contacted, with 9 providing written consent to participate (response rate 69.2%). Their demographic details are displayed in Table 1, aided by Mintzberg's organisational structure theory (1993). Initially individuals were selected due to their prominent position, for example Councillor C1 who create the Housing and Community Wellbeing portfolio. From this, the snowball sampling method was employed, where interviewees recommended individuals, they believed would be fundamental. Data collection took place until saturation was achieved and no new themes emerged.

Table 1: Interview participants

Code	Gender	Role	Positioning
C1	Male	Councillor	Strategic apex
C2	Male	Director of Place	Strategic apex
C3	Male	Service Coordinator	Technostructure
C4	Male	Area Based Scheme Coordinator	Middle line
C5	Male	Head of Property and Maintenance	Middle line
C6	Female	Housing Services Lead	Middle line
C7	Male	Housing Officer	Operational
C8	Female	Housing Occupational Therapist	Operational
C9	Male	Head of Adaptations	Operational

To ensure coherence and consistency, a standard interview guide containing questions and probes was created to guide the conversation with a neutral approach adopted, asking no leading questions. Interviewees were asked questions related to three topics: the strategy and model of retrofit practice, collaborative practice and the alignment of their role within the 'ageing in place' agenda. The results underwent thematic analysis, allowing for an abductive approach of inquiry (Braun and Clarke, 2006). The results were analysed using the 6 phases of thematic analysis outlined by Braun and Clarke (2006). The first phase involved becoming immersed in the data during transcription and repeatedly reading the data solidify personal understanding of the text. The data was coded for key words, phrases and sentences which indicated recurring, meaningful and interesting patterns. The codes were then re-focused at the broader level of conceptual themes. Once themes emerged, these were reviewed and refined, and representative extracts were selected. Within this, an iterative approach was implemented, where the emerging data was informed and consistently reviewed by current literature and the theoretical framework of institutional theory.

DATA ANALYSIS

From analyses, five key themes arose: barriers of governance, fragmentation, data infrastructure, dereliction of skills and communication and knowledge share.

Barriers of governance

The structures of government funding allocation differ between organisations, creating limited efficacy of planned works as C1 Councillor states, "we are given grants over three years, whereas the energy agency work year to year…there could be good savings to work like external cladding at the same time as roof repair because the staging is there…we can't plan because we don't know their funding". However, C4 ABS comments that there are wider issues that could potentially arise from their funding structures, "we have to deliver a policy or programme very quickly…it's a case of get the money, get the bodies on site…we are doing significant work to people's homes and getting it wrong it can be catastrophic". Showcasing the potential for detrimental consequences on the house and health of the resident if proper procedure is not followed; catalysing erratic and absentminded results, due to neglection of the criticality of the task. Furthermore, C4 ABS states that internal structures and governance inhibits projects, with its vast structure and focus on efficiency, or appearance of efficiency, creating significant obstructions, "(SHP) have went through a major restructuring…there's been a lot of uncertainty…we have felt that because you can't pin anyone down to make a decision or even point you in the direction of who to talk to".

Fragmentation

Discussing the integration of retrofit practice between housing, energy and health, a key emergent theme was fragmentation between the sectors, despite being state funded and controlled. This can be understood by C1 Councillor's comments, " we could target people coming out of hospital but there is a breakdown in communication with health and we don't know who is in hospital…they report to their bosses but they should report to us too and that is how you get bed blocking", this view was echoed by C6 Housing Lead, "we go round in circles…they are looking at their budget and we are looking at ours…it's an 'that is your responsibility, that is not our responsibility' kind of thing" and Director C2, "the potential cost to the NHS from delayed discharge could be £25,000, whereas we could spend £12,000 on adaptations to get them home, but how do we get those connections?". Thus, displaying the impact of silo-based funding and policies, preventing interconnections and fragmenting services when there are mutual benefits. However, there are individuals trying to combat this barrier, actively making the connections the council cannot, as seen by C4 ABS, "(ABS) is a joint project with the NHS, they have been very involved in the design and monitoring process" displaying that meaningful connections and collaborative practice between energy and health can not only possible, but successful.

Data infrastructure

A vital issue which arose was the poor infrastructure in place creating reduced efficiency and increased cost. This is seen within C3 Coordinator's example, "I was asked why we weren't doing EWI to a property, I stated the data said it was already insulated…they had issues of dampness, previous insulation had been removed but never replaced, but our data showed it there…his son was diabetic and they couldn't keep his room warm…I know 16 properties in (location) alone which they declare pass (SHQS/EESH) which wouldn't". This issue was reinforced by Housing OT C8, "the record will say there is a ramp, but that was taken out and never up-dated…or I ask for a wet floor shower but something changes…what actually happens is different but our records will still say wet floor shower" displaying the vast extent of this problem, of insufficient recording procedures, impacting not only future planned

works but the health and wellbeing of vulnerable residents. This was experienced externally by C4 ABS, "the quality of data is questionable…we know 50 houses that had insulation extracted because something went wrong but there is no record of that" and explains a key reason for this is the aversion to systematic procedure and technology in the past, "they had a person for 30 years, a bank or knowledge, but that is lost, not just skillset, but the information because there are no records…it surprised me how little the council knows about their own stock", displaying the deep-rooted difficulties, which can be backdated to historic work, and still creating substantial problems to date.

Dereliction of skills

Following years of austerity cuts few inhouse skills have been retained, resulting in an over reliance upon subcontractors, as C5 Prop and Main states, "some of the work we are asked to do, we can't because we don't have the traders or ability, so it has to go to an external contractor" and is reinforced by C4 ABS, "SHP outsource everything, they don't even do their own health and safety anymore, they have one full-time and one part-time clerk of works for all council work…we have never been able to rely on them". This displays the impact and lack of trust in ability, resulting in them having to invest themselves to ensure high standards. Within the SHP, there is dissatisfaction with these circumstance and a desire for change, with C6 Housing Lead commenting, "Energy Agency (ABS) are really good at working with us but we need more skills to be honest; to be able to go and do what we need to do (meeting EESH standards)". However, C3 Coordinator is trying to change this practice, seeing the economic and decision-making mistakes, as seen by his introduction of a salaried architect "his commission was for only planning applications for ramps, so if we wanted a housing warrant for a bathroom adaptation or building warrant, he wasn't allowed and we had to get someone else…now it's streamlined and he does everything".

Communication and knowledge share between stakeholders

Following discussion it emerged that there was serious fragmentation within communication and knowledge share in the SHP, creating increased cost through a disjointed approach to retrofit practice, as C3 Coordinator experienced, "we were doing fire resistant work, pipes and electrical work were penetrating walls, property and maintenance went in with expanding foam…it went everywhere, it was someone who didn't care and just fired it in…I am now paying a contractor to clean it out and get back to where we started" and reinforced by his example of, "(tenant) had a motorised wheelchair, I discovered from the OT property and maintenance installed a new door with a large threshold…poor chap couldn't get in his own house…its bonkers, the joiner sees the tenant and ramp, yet puts in a door with a threshold you have to step over…they're just going purely by data or whatever". This creates the question of wider thinking, and an overriding focus upon data and orders prevailing above the consideration of tenants and need. This concept of communication across departments has polarised views, with Director C2 stating, "in years past people were very myopic in terms of what was in front of their noses…now people are reaching out and share practice and knowledge…they understand the opportunities" however, C3 states, "it's a thing we've forgotten, we sit in our splendid isolation and fire out an email…go speak to them, understand what they are about and let them understand you" displaying opposed views from a strategic to practical view of the factual levels of communication and knowledge share practically implemented in retrofit practice.

DISCUSSION

Institutions are networks through which political interests interact and compete, therefore shaping and constraining subsequent choices (Hall and Taylor, 1996). State social housing holds a unique position within the sector; government funded and regulated, it must not only care for the most vulnerable, but be accountable to the people. Thus, is it imperative that retrofit practice takes a holistic, innovative approach to the cross-sector problems aligned with the global issue of an ageing population. Neoliberalism, characterised by marketisation, privatisation and deregulation, holds the perception that social good is maximised by expanding the reach and frequency of market transactions (Bourdieu, 1998). The establishment of NPM, coupled with a decade of fiscal restraints due to an ideologically driven austerity agenda has created a target-driven culture that is reluctant to take on institutional responsibility (Heald and Steel, 2018). Through data analysis, it was clear that this agenda and philosophy has impacted skills and knowledge base within retrofit practice: creating increased pressure and restricting internal and cross-sector collaboration through a focus upon calculable outcomes. Institutional theory aids in explaining how both deliberate and inadvertent choices lead organisations to mirror the norms, values and ideologies of the field. As a result, meeting the environment's expected characteristics, thus receiving legitimacy (Lepsius, 2017). Weber (1958) described these expectations and social pressures as the "iron cage", where institutions are pushed towards isomorphic forms of normative behaviour; becoming identical to those within the same sector. Institutions can only escape this by transforming their environmental expectations, with their environment holding a reduced deterministic role (Lepsius, 2017). Therefore, it could be asserted that social housing follows the concept of mimetic isomorphism (DiMaggio and Powell, 1983), with current practice viewed as successful and legitimate within the field. However, if this fragmented practice is deemed acceptable, as best practice, then there is a vital need for change-for the boundaries and very definition of collaboration to be redefined into one which incorporates all aspects of care. There is a need to break through the deep-rooted intrinsic barriers created within the defined boundaries of policy and budget and see the public sector for what it is: An institution in place to maintain the wellbeing and prosperity of the population. Moreover, within Foucault's concept of Governmentality (1982), he referred to the power struggles felt within neoliberal societies. This is clearly visible within the power relations across different sectors: seeking to protect their budgets and follow direct sectorial rule, therefore releasing responsibility of care unto others. Although emergent from neoliberal practices such as performance benchmarking and increased pressure due to economic restraint, this is accentuated by the institutional structures of silo-based funding, policies and hierarchical structures within the public sector. These highly bureaucratic organisations outlined by Weber (1958) are resistant to change. The prevailing atmosphere of control and predictability favours continuity and is threatened by change and innovation. However, there must be a repositioning in the minds of those implementing retrofit practice, creating a view focused upon the needs of the individual within the wider setting, rather than focusing on individual agendas (Rodger *et al.,* 2018). These boundaries must be released, and a renewed focus formed within the context of an ageing population and the significant implications for public policy across housing, health, energy and welfare provision realised. Thus, shifting from the management and implementation of a single sector delivery, to an inclusive, integrated, agenda with mutual benefits across the public sector.

CONCLUSIONS

There is a need for greater levels of integration within retrofit practice, not only to improve the wellbeing of the older population, but to increase efficiency and economic savings within public services. Fundamental change must occur in the way in which housing, health and energy sectors interpret themselves; there must be a realisation that all funding, policies and regulations arise from one source, a source with the exclusive aim of the maintenance and care of the population. The hierarchical structures with silo-based application have created the belief that each sector are separate entities with separate agendas, however these are government and social constructed boundaries. These are interlinking agendas, with a much broader economic and social impact and this is particularly significant when looking at the global agenda of ageing in place. Therefore, there is a need for a system-wide recognition of the potential benefits of cross-sector collaboration, and a step back from the neoliberal values in place: understanding the potential for reduced cost and dependency upon state through increased knowledge share and collaboration within retrofit practice. Key areas of future research include undertaking a multiple case study research of social housing providers within different geographic locations to test emergent theories and increase generalisability across the UK and wider international world. Furthermore, there is a need to examine the perceptions and impacts upon the ageing population residing within social housing to determine their perceptions and the potential for a greater participatory approach to retrofit practice and policy.

REFERENCES

Abdul-Aziz, A R, Jaafar, M, Nuruddin, A R and Lai, S W (2010) Using institutional theory and resource-based perspective to aid transformation of housing-related public enterprises in Malaysia, *Habitat International*, 34(**2**), 196-203.

Bourdieu, P (1998) *The Essence of Neoliberalism: What is Neoliberalism? A Programme for Destroying Collective Structures Which May Impede the Pure Market Logic: Utopia of Endless Exploitation*. Le Monde Diplomatique.

Boyle, F and Thomson C (2016) Establishing an evidence base for adapting social housing for an ageing population, *Journal of Financial Management of Property and Construction*, 21(**2**), 137-159.

Braun, V and Clarke, V (2006) Using thematic analysis in psychology, *Qualitative Research in Psychology*, 3(**2**), 77-101.

Bresnen, M (2010) Keeping it real? Constituting partnering through boundary objects, *Construction Management and Economics*, 28(**6**), 615-628.

Buser, M and Carlsson, C (2017) What you see is not what you get: Single-family house renovation and energy retrofit seen through the lens of sociomateriality, *Construction Management and Economics*, 35(**3**), 276-287.

DiMaggio, P J and Powell, W W (1983) The iron cage revisited: Institutional isomorphism and collective rationality in organizational fields, *American Sociological Review*, 48(**2**), 147-160.

Eisenhardt, K M (1989) Building theories from case study research, *Academy of Management Review*, 14(**4**), 532-550.

Foucault, M (1982) *The Subject and Power*. Brighton, Sussex: Harvester Press.

Hall, P and Taylor, R C (1996) Political science and three new institutionalisms, *Political Studies*, 44(**5**), 936-957.

Hawley, A H (1968) Human ecology (4). *In:* Sills, D L (Ed.) *International Encyclopaedia of Social Sciences*. New York: Macmillan, 328-337.

Hayes, R L and Oppenheim, R (1997) Constructivism: Reality is what you make it. *In:* Sexton, T and Griffins, B, *Constructivist Thinking in Counselling Practice, Research and Training*. New York: Teachers College Press, 19-40.

Heald, D and Steel, D (2018) The governance of public bodies in times of austerity, *The British Accounting Review*, 50(**2**), 149-160.

Hood, C (1991) A public management for all seasons? *Public Administration*, 69(**1**), 3-19.

Jacobs, K, Berry, M and Dalton, T (2013) 'A dead and broken system?': 'Insider' views of the future role of Australian public housing, *International Journal of Housing Policy*, 13(**2**), 183-201.

Lepsius, M R (2017) Interests and ideas: Max Weber's allocation problem. *In:* Wendt, C (Eds.) *Max Weber and Institutional Theory*. Cham: Springer.

Mills, J, Bonner, A and Francis, K (2006) The development of constructivist grounded theory, *International Journal of Qualitative Methods*, 5(**1**), 25-35.

Mintzberg, H (1993) *Structures in Fives: Designing Effective Organizations*. Englewood Cliffs, NJ, US: Prentice-Hall, Inc.

Mullins, D, Reid, B and Walker, R M (2001) Modernization and change in social housing: The case for an organizational perspective, *Public Administration*, 79(**3**), 599-623.

Power, E R and Bergan, T L (2018) Care and resistance to neoliberal reform in social housing, *Housing, Theory and Society*, 1-23.

Rasmussen, G M G, Jensen, P L and Gottlieb, S C (2017) Frames, agency and institutional change: The case of benchmarking in Danish construction, *Construction Management and Economics*, 35(**6**), 305-323.

Rodger, D, Callaghan, N and Thomson, C (2018) Are retrofitted social houses sufficiently reflecting the holistic health and wellbeing requirements of older people? *In:* Gorse, C and Neilson, C J (Eds.) *Proceedings of the 34th Annual ARCOM Conference*, 3-5 September 2018, Belfast, UK, Association of Researchers in Construction Management, 219-228.

Rummery, K (2009) Health Partnerships, healthy citizens? An international review of partnerships in health and social care and patient/user outcomes, *Social Science and Medicine*, 69(**12**), 1797-1804.

Saidur, R (2009) Energy consumption, energy savings and emission analysis in Malaysian office buildings, *Energy Policy*, 37(**10**), 4104-4113.

Sanderson, I (2002) Evaluation, policy learning and evidence-based policy making, *Public Administration*, 80(**1**), 1-22.

Shelter (2007) *Older People and Housing*, Shelter.

Smiley, J P, Fernie, S and Dainty, A (2014) Understanding construction reform discourses, *Construction Management and Economics*, 32(**7-8**), 804-815.

Suttor, G (2011) Offset Mirrors: Institutional paths in Canadian and Australian social housing, *International Journal of Housing Policy*, 11(**3**), 255-283.

Van Hees, S, Horstman, K, Jansen, M and Ruwaard, D (2017) Photovoicing the neighbourhood: Understanding the situated meaning of intangible places for ageing-in-place, *Health and Place*, 48, 11-19.

Weber, M (1958) *The Protestant and the Spirit of Capitalism*. New York: Scribner.

EFFECTS OF GREEN RETROFITS: A CASE OF INDUSTRIAL MANUFACTURING BUILDINGS IN SRI LANKA

Achini Shanika Weerasinghe[1], Thanuja Ramachandra[2] and Amalka Nawarathna[3]

[1&2] *Department of Building Economics, University of Moratuwa, Moratuwa, 10400, Sri Lanka*

[3] *Department of Architecture and Built Environment, Northumbria University, Newcastle Upon Tyne, UK*

The impact of built environment on the global warming, greenhouse gas emissions and natural resources depletion is staggering. Consequently, existing built environment will have very high responsibility in dealing with global issues, unless the rate of green retrofitting is amplified. Existing buildings are accountable for 39% of energy use and 35% carbon dioxide emissions, whereas, green retrofitting can achieve 40%-60% energy saving, which contributes 20%-30% carbon emission reduction. Nevertheless, the building owners are less willing to pay for retrofits due to high initial cost and identifying the most cost-effective retrofits for a particular project is still a major challenge. The current study therefore analyses the costs and saving implications of various green retrofits incorporated into an industrial manufacturing building in Sri Lanka. The study used mixed methods in data collection where professionals involved in green retrofits industrial manufacturing buildings were interviewed to identify the green retrofit technologies implemented and the reasons for selection of those green retrofits and subsequently a detailed costs and saving potential analysis of green retrofits incorporated in the selected green retrofit certified industrial manufacturing building was performed using Net Present Value and Simple Payback Period. The analyses show that the use of retrofits related to energy, indoor environmental quality and water are at a significant level in industrial manufacturing buildings in Sri Lanka. Moreover, the implemented retrofit projects indicate the financial viability of green retrofits with positive net present values and simple payback period of less than 5 years. Considering the lifetime financial returns of those retrofits, each indicates significant benefits compared to initial investment. Therefore, the success of these actual retrofit scenarios would enable to identify the most appropriate retrofits based on the potential expenses and returns involved, and thereby assist building investors to incorporate most feasible retrofits into their existing buildings.

Keywords: cost, green buildings, retrofits, Sri Lanka, sustainability

INTRODUCTION

The majority of existing buildings are designed for long lifespan and expected to be in use for another 50-100 years (Love and Bullen 2009). These existing buildings have already utilised energy when procuring, manufacturing, transporting materials and constructing the building. Thus, replacing an existing building with a new green

[1] thanujar@uom.lk

Weerasinghe, A S, Ramachandra, T and Nawarathna, A (2019) Effects of Green Retrofits: A Case of Industrial Manufacturing Buildings in Sri Lanka *In:* Gorse, C and Neilson, C J (Eds) *Proceedings of the 35th Annual ARCOM Conference,* 2-4 September 2019, Leeds, UK, Association of Researchers in Construction Management, 842-851.

building would take more than 65 years to regain the energy utilised during the whole life-cycle and this is counter-productive to the idea of sustainability (Du Plessis 2007; Township's Boards of Historical and Architecture Review 2008). To this end, Liang, Peng and Shen (2016) and Wilkinson, James and Reed (2009) stressed that the existing buildings should give due consideration to green retrofitting. In fact, green retrofit enables, upgrading existing building towards energy and environmental performance, reduce water use, and improve comfort and quality of space in terms of natural lighting, air quality and noise, in a way that it is financially beneficial to the owner (United States Green Building Council [USGBC] 2003).

However, Davies and Osmani (2011) found that the building owners are unwilling to pay for retrofits due to high initial cost. According to McDonald, Ivery and Gagne (2008), the first costs for green space may be acceptable for new construction but any improvements to existing space require capital expenditure. In fact, Rehm and Ade (2013) found that, green retrofits such as installation of high-performance cladding systems, implementation of rainwater harvesting systems and use of energy-efficient mechanical equipment are very expensive. On the contrary, Zhai, Reed, and Mills (2014) argued that the owners and occupiers are willing to invest on green retrofitting due to reduced construction costs compared to new construction. Notwithstanding, most of the organisations are motivated to invest on energy efficient retrofitting due to lower operation costs and high return on the investment (McGraw-Hill Construction 2009). As per Bond (2010), renewable energy projects provide high return on major investment within a short payback period. However, Kasivisvanathan, Ng, Tay and Ng (2012) stated that the industries are unenthusiastic about green retrofits due to the long payback periods.

In Sri Lanka, Karunaratne and De Silva (2019) revealed that the most commonly used energy retrofit techniques in office buildings were variable frequency devices, LED lighting and low emissivity coatings. Further, Fasna and Gunatilake (2018) identified forty-two (42) barriers affecting successful adoption of energy retrofits in existing hotel buildings, where lack of transparency about energy cost and use and difficulties in properly identifying the energy saving from the retrofitted system are identified as significant barriers. Considering the current green retrofitting situation in Sri Lanka, cost implications and savings throughout the life-cycle should be tracked for green retrofit projects in order to improve the implementation of retrofits. On the other hand, Sri Lankan industrial manufacturers are highly motivated to incorporate green features in the buildings due global clients' pressure on comply with energy and environmental regulations (Weerasinghe and Ramachandra 2018). However, a limited number of buildings have been certified for incorporation of green features. In fact, Weerasinghe and Ramachandra (2018) analysed the profile of the green certified buildings that are registered in USGBC and identified that 47 buildings have been green certified to date, while only 7 industrial manufacturing buildings were implemented green retrofits. Therefore, the current study examines the cost implications and saving potentials of green retrofits in industrial manufacturing buildings in Sri Lanka.

Application of Green Retrofits

Policy makers have acknowledged the retrofitting in the company's vision and environmental policy as a way of promoting sustainability in the built environment (Wilkinson, James and Reed 2009). Further, Liang, Peng and Shen (2016) explained that the green retrofit for existing buildings should be given due consideration to

reduce energy consumption and GHG emission. Accordingly, previous authors studied the application of green retrofits and significant savings achieved. Table 1 presents the various green retrofits adopted in building with respect to sustainable focus areas of: sustainable sites (SS), energy and atmosphere (EA), water efficiency (WE), material and resources (MR), and indoor environmental quality (IEQ) based on LEED rating system.

Table 1: Application of green retrofits

	Green Retrofits/Technologies	Sources
EA	Use of energy efficient lighting/plugs, improvement of luminaries and installation of reflectors, use of time-scheduled control	Dascalaki and Santamouris (2002)
	Install heating controls, waste heat recovery, improvement of heating system equipment, preheat upgrade	Fluhrer, Maurer and Deshmukh (2010) Mahlia *et al.,* (2005)
	Implement energy-efficient equipment and appliances; chiller plant retrofit, cooling tower replacement	Chidiac, Catania, Morofsky and Foo (2011)
	Adoption of renewable energy; geothermal, wind, biomass and biogas technologies, solar collectors and PV cells	
	Boiler efficiency economizer and replacement with a condensation gas heater	Fluhrer *et al.,* (2010)
	Insulation of walls, window replacement and upgrading, decrease of window area, cladding replacing and insulations, change of glazing system, low-e double glazing	Dascalaki and Santamouris (2002)
	Install a building management system	
	Use of energy meters on major mechanical systems and sub metering for all systems	Aktas and Ozorhon (2015)
	Implement demand control/mechanical ventilation, provide natural ventilation, air sealing of ventilation system, air infiltration reduction, install CO2 sensors	Aktas and Ozorhon (2015)
IEQ	Install day light sensors, manual or occupant sensing device, motion control systems, Automatic photocell-based controls	Chidiac *et al.,* (2011)
	Use sky lights, task lights	Dascalaki and Santamouris (2002)
	Install insulated reflective barriers, exterior and interior permanent shading devices	Fluhrer *et al.,* (2010)
	Construct green/vegetated roof, use high emissivity roof, roof insulation	
SS	Provide bicycle racks, changing facilities, parking spaces and alternative-fuel refuelling stations	Aktas and Ozorhon (2015)
	Construct open grid paving, use high-albedo materials and light-coloured surface (white asphalt)	
	Install low-flow showerheads, install automatic controls dry fixture and fittings	
WE	Implement grey water and rainwater recycling systems, micro irrigation systems	Aktas and Ozorhon (2015)
	Install a building-level water meter and subsystem-level water meters	
MR	Use environmentally friendly finishes	McGraw Hill Construction (2009)

As shown in Table 1, majority of green retrofits were identified under the EA category which ensure reduce energy consumption and GHG emission. These include lighting, heating, air conditioning, renewal energy, boiler efficiency, building envelop, building management and energy monitoring related retrofits. Amongst, most of the authors focused on using energy efficient lighting and improving heating systems due to the

significant savings. For example, Mahlia, Said, Masjuki and Tamjis (2005) highlighted significant energy and cost savings of $37 to $111 million through retrofitting incandescent lamps with compact fluorescent lamps. Further, installing energy efficient air conditioning systems, adoption of renewable energy, improving boiler efficiency, building envelop, installing a building management system and use of energy meters were also highlighted by few authors. For example, Dascalaki and Santamouris (2002) conducted a study on the energy conservation potential of retrofits using computer simulations for five office building and concluded that building interventions on the envelope, HVAC, artificial lighting systems, and passive improvements on heating and cooling reduce total energy use by 48% to 56%. Another study, Chidiac *et al.,* (2011) simulated that retrofits such as heat recovery, daylighting, boiler efficiency economizer, preheat upgrade and lighting load reduction, reduce 20% of electricity consumption in Canadian office building.

In terms of IEQ, improvement in ventilation systems, installing lighting sensors and controllers, use of sky lights, installing insulation and shading devices were highlighted by previous authors. In fact, Fluhrer *et al.,* (2010) revealed that use of these retrofits reduce 105,000 metric tonnes of CO2 emission over the next 15 years. Similarly, considering SS feature, Aktas and Ozorhon (2015) highlighted green retrofits such as upgrade of roofs, provide alternative transportation facilities and improvements for the heat island reductions collectively save energy up to 25%. In terms of WE feature, the highlighted green retrofits were installation of water saving features, implement grey water and rainwater recycling systems and installing water meters. Further, Aktas and Ozorhon (2015) found that use of these retrofits under SS and WE features contribute to significant energy and water savings. However, there seems the integration of retrofits of MR category is comparably less in the buildings.

The above review of literature indicate that green retrofits reduce the operation costs and contribute to savings during the life-cycle, which subsequently reduce whole life cost of the building. Although, these studies have emphasized the effects of green retrofits towards energy efficiency, the actual cost implications are not discussed for each retrofit. Building owners and decision makers are often faced with the challenge of identifying and implementing an optimal set of green retrofits that can maximize the sustainability of their buildings while minimizing the required cost. Therefore, the current study focuses on analysing the cost implications and potential savings of green retrofits implemented in an industrial manufacturing building in Sri Lanka towards recommending the feasible green retrofits.

RESEARCH METHODS

The research was approached using mixed methods where it involved collection of both qualitative and quantitative data related to green retrofits of industrial manufacturing buildings using semi-structured interviews and document analysis.

Initially, the profile of green certified buildings under LEED O+M Existing Building category was studied and found that there were 7 industrial manufacturing buildings certified under different versions of existing buildings, with varying business function, certification level, and green space type, as shown in Table 2. Of those buildings, GB1, GB2, GB3 and GB4 were considered for the study as they were certified under the same rating system and in the same business category. Initially, semi-structured interviews were conducted among professionals such as facilities managers and maintenance managers/engineers who engaged in those industrial manufacturing retrofitting in order to identify the green retrofit technologies implemented and the

reasons for selection of those green retrofits. Table 3 presents the profile of the participants which represents work positions, experience and field of expertise of those participants. Subsequently, a detailed analysis into cost implications and potential savings of green retrofits implemented was performed for a selected single case building, GB1 which achieved the highest certification level (Platinum).

Table 2: Profile of green buildings certified under LEED existing buildings category

Building	Rating System (Version)	Certification	Green Space	Business
GB1	LEED O+M: Existing Buildings (v2009)	Platinum	Industrial Manufacturing	Garment
GB2		Gold		Garment
GB3		Gold		Garment
GB4		Silver		Garment
GB5		Gold		Spirits and Wines
GB6	LEED O+M: Existing Buildings (v2.0)	Platinum		Garment
GB7	LEED O+M: Existing Buildings v4.0	Gold	Warehouse	Logistics

The data collected through semi-structured interviews were analysed using manual content analysis. Net Present Value (NPV) and Simple Payback (SPB) were used to determine the life time gain of the project considering the time value of money and time to recover the initial capital cost paid for the project respectively (BSI, 2008). The NPV analysis was carried out for expected life time of retrofits, at the discount rate of 4.26 percent obtained from the Central Bank of Sri Lanka. It was assumed that a similar annual monetary saving would be earned throughout the life time of the project and no scrap value was taken at the end of the project.

Table 3: Profile of Participants

Building	Interviewee	Designation/Position	Work Experience (Years)	Profession/Field of Expertise
G1	I01	Chief Maintenance Engineer	18	Mechanical Engineering
G2	I02	Maintenance Manager	17	Electrical Engineering
G3	I03	Facility Manager	9	Facilities Management
G4	I04	Factory Engineer	16	Mechanical Engineering

DATA ANALYSIS AND FINDINGS

The findings of the semi-structured interviews on the green retrofits implemented in the selected four industrial manufacturing buildings, the reasons for the implementation of green retrofits and analysis of cost implications of green retrofits are presented in the following sections.

Application of Green Retrofits in Industrial Manufacturing Buildings

Sustainable Sites (SS)

Sustainable sites offer several green retrofit technologies that could be incorporated in transforming an existing building to a green. All the interviewees (I01, I02, I03 and I04) agreed that the green features such as bicycle racks, changing facilities, parking spaces to provide alternative commuting transportation, and paving surfaces to reduce heat Island effect were implemented to the respective buildings at the initial stage. Further, the interviewees (I01, I03 and I04) explained that the light-coloured roofing to reduce the heat island effect was implemented in the respective buildings. Additionally, according to the interviewees (I01, I02 and I03), the respective buildings

have already implemented low reflectance surfaces to reduce the light pollution. Overall, all the interviewees confirmed that these green features were implemented at the initial stage of the buildings.

Water Efficiency (WE)
Similar to SS, all the interviewees (I01, I02, I03 and I04) confirmed that green technologies such as water meters, automatic controls, dry fixture and fittings and greywater recycling were already implemented in the respective buildings at the initial stage. Therefore, these retrofits were not considered at the sustainability transition of the respective buildings. However, the interviewee (I01) responded that the existing building (GB1) was upgraded using green retrofits such as sub system level water meters and low water flow push taps to further improve the water sustainability of the building. Accordingly, nowadays, most of the building owners invest on sustainable water features at the initial stage of the buildings, rather than waiting to implement these features at the operation and maintenance stage.

Energy and Atmosphere (EA) and Indoor Environmental Quality (IEQ)
Unlike, SS and WE, all the interviewees (I01, I02, I03 and I04) indicated that the focus on energy efficiency was less at the initial construction of those buildings due to cost considerations. Therefore, a considerable number of energy improvements were made when converting those existing buildings into green. According to the interviewees (I01, I02, I03 and I04), the green retrofits such as sky lights, LED lights, steam line insulation and compressed air line modification were used to optimize energy efficiency performance and biomass boiler were implemented in the respective buildings. The interviewees (I01, I02 and I03) mentioned that the system level energy metering has been implemented in the respective buildings. Accordingly, all most all the interviewees agreed that energy retrofits were given the top most priority over other retrofits due to the economic savings.

In terms of IEQ, all the interviewees confirmed (I01, I02, I03 and I04) that installation of sky lights provide the daylight into building, installation of LED bulbs as task lighting for the sewing machines reduce the energy consumption. The interviewees (I01, I02) agreed that the respective buildings have introduced evaporative cooler, energy efficient chiller and VSDs for chiller to ensure the demand control and air infiltration reduction of ventilation system. Overall, all the interviewees confirmed that few of the energy retrofits indicate both energy efficiency and IEQ and those retrofits were used to ensure the ventilation and lighting aspects of the buildings.

Materials and Resources (MR)
In terms of material and resources, all the interviewees agreed that retrofits in this category have given the least priority in the respective buildings, while, the focus has given to sustainable purchasing of consumables and solid waste management. However, the interviewee (I01) explained that existing steel racks used to store the materials were replaced by environmentally friendly plywood racks and environmentally friendly finishes such as zero VOC paints were used for interior wall finishing.

Cost Implications of Green Retrofits in the Selected Industrial Manufacturing Building

The initial costs and annual savings of green retrofits integrated in the GB1 industrial manufacturing building were extracted from relevant documents and subjected to NPV and SPB analyses. In performing NPV and SPB analyses, costs savings achieved due to reduction of energy, water and other resource consumptions through

the implemented green retrofits were considered as cash inflows and the initial investment costs were considered as cash outflows of the projects. Table 4 presents the cost implications (NPV and SPB) of green retrofits in the selected building.

As seen from Table 4, twelve (12) energy retrofits and two (02) water retrofits were implemented in the selected building which have positive NPV values and payback period of less than 5 years. Amongst, replacing existing chiller system with evaporative cooler has the highest NPV of LKR 138,947,770 which recovers the initial investment cost with a shot payback time (0.31 years). The retrofit with second highest NPV (LKR 83,381,330) is replacing oil fired steam boiler with biomass boiler with a payback period of 1.52 years. Other retrofits with higher costs savings are low water flow push taps, replacing existing chillers with energy efficient chiller, sub system level water meters, replacing clutch motors with servo motors and replace T8 lamps with LED lights etc. Amongst, the green retrofit: Installation of low water flow push taps has the lowest payback time of 0.004 years with a NPV of LKR 53,428,094. The payback period of most of the green retrofits is less than three years. However, replacing existing chillers with energy efficient chillers (4.28 years) and replacing florescent lamps with sky lights (4.16 years) have payback periods more than three years. Considering the NPV and SPB values obtained, it is viable to invest on all the identified green retrofits, nevertheless, the green retrofits with payback of more than three years would be unattractive to those who expect fast investment returns within first three years of the investment.

CONCLUSIONS

Application of green retrofits in the industrial manufacturing buildings in Sri Lanka was examined through the semi-structured interviews. Overall, the interviews confirmed that the respective buildings have implemented energy, IEQ and water related retrofits, whereas in terms of sustainable sites and materials, green features were implemented at the initial stage of the building and they were not incorporated to the existing building at the sustainability transition stage. Accordingly, the current study highlighted that green retrofits such as sky lights, LED lights, steam line insulation, compressed air line modification, biomass boiler, evaporative cooler, energy efficient chiller and VSDs were implemented in the industrial manufacturing buildings in Sri Lanka in terms of energy and IEQ. Similarly, most of these energies and IEQ retrofits were identified in the previous studies by Aktas and Ozorhon (2015), Chidiac *et al.,* (2011), Dascalaki and Santamouris (2002), Fluhrer *et al.,* (2010) and Mahlia *et al.,* (2005). Additionally, the selected buildings were upgraded using green retrofits such as sub system level water meters and low water flow push taps which were identified in the study of Aktas and Ozorhon (2015).

Moreover, previous studies, Dascalaki and Santamouris (2002) considered building envelope retrofitting as a key to improve energy performance of buildings. However, the respondents of the selected green cases confirmed that the respective buildings haven't done any upgrades to the building envelope other than the existing building conditions. Contradictory views were indicated by previous studies on the initial cost of green retrofits (McDonald *et al.,* 2008; Zhai *et al.,* 2014). The positive NPV values in the current study indicate the significant financial returns over the initial investment. Moreover, the findings on payback period differ to literature findings which indicate that the green retrofits involved long payback periods (Kasivisvanathan *et al.,* 2012). Bond (2010) indicated that the renewable energy projects provide high

return on major investment within a short payback period, likewise the payback period equals to 1.4 years and in terms of biomass boilers.

Furthermore, most of the green retrofit projects have recovered the higher initial investment very quickly within less than 3 years, except the energy efficient chillers and sky lights. In terms of costs savings of green retrofits, Mahlia *et al.,* (2005) highlighted significant cost savings of retrofitting incandescent lamps with compact fluorescent lamps.

Table 4: Cost implications of green retrofits

Green Retrofit	Investment (LKR)	Annual Saving	Savings (LKR) Annual	Savings (LKR) Life-cycle	NPV(LKR)	SPB (Years)	Life-cycle (Years)
Replace existing chillers with evaporative cooler	4,098,510	935766 kWh	13,100,735	143,046,280	138,947,770	0.31	15
Replace oil fired steam boiler with biomass boiler	10,745,700	506173 kWh	7,086,423	94,127,030	83,381,330	1.52	20
Install low water flow push taps	50,450	201676801	12,100,608	53,478,544	53,428,094	0.004	5
Replace existing chillers with energy efficient chillers	20,475,000	341640 kWh	4,782,960	59,289,197	38,814,197	4.28	18
Install sub system level water meters	1,003,507	133120001	7,987,200	35,299,369	34,295,862	0.13	5
Replace clutch motors with servo motors	1,797,600	225763 kWh	3,160,690	29,220,793	27,423,193	0.57	12
Replace T8 lamps with LED lights	2,241,366	135869 kWh	1,902,169	12,670,435	10,429,069	1.18	8
Insulate steam lines	183,000	178530	2,499,420	9,017,314	8,834,314	0.07	4
Replace florescent lamps with sky lights	4,680,000	80308 kWh	1,124,323	10,394,442	5,714,442	4.16	12
Compressed air line modification	795,450	115227 kWh	1,613,181	3,031,314	2,235,864	0.49	2
Implement a biogas project	1,265,540	36072 kWh	505,015	3,363,928	2,098,388	2.51	8
Install VSD for chiller	475,000	12117 kWh	169,642	1,129,993	654,993	2.8	8
Install VSD for compressor	150,600	3814 kWh	53,400	355,700	205,100	2.82	8
Recovery of flash steam for water heating	80,000	3928 kWh	55,000	198,427	118,427	1.45	4

Per l cost of water = LKR 0.60; Per kWh cost = LKR 14.00

While, the current study revealed that energy retrofits such as use of evaporative cooler, biomass boiler, energy efficient chillers and servo motors provide much economical savings over life-cycle. Accordingly, the study recommends the appropriate green retrofits options such as evaporative cooler, biomass boiler, low water flow push taps, energy efficient chillers, water meters, servo motors, LED lights, steam lines insulation, sky lights, compressed air line modification and biogas project, which provide higher return within a short time.

The lack of knowledge on life-cycle cost and long-term return of green retrofits lead to decisions not to implement green retrofits. Further, the investors who do not have access to enough information will not realize the contribution of green retrofits

towards energy, environmental and water performance, comfort and quality of space etc. Lack of knowledge on financial institutions and unawareness of the benefits of green retrofits have primarily affected building owners from implementing green retrofit projects. To this end, the findings of the current study highlight the financial viability of the implemented retrofit projects under water efficiency, energy and IEQ with positive NPV values and less SPB periods. Moreover, considering the life time financial returns of those retrofits, each indicates significant benefits compared to the initial investment. Therefore, the success of these real retrofit scenarios would enable to identify the most appropriate retrofit technologies that can maximize the sustainability of their buildings while minimizing the required cost. Thereby, building investors and owners could apply those retrofits in existing buildings without uncertainty.

ACKNOWLEDGEMENT

Authors highly acknowledge and appreciate the financial support given by the Senate Research Committee of University of Moratuwa under Grant SRC/ST/2018/11.

REFERENCES

Aktas, B and Ozorhon, B (2015) Green building certification process of existing buildings in developing countries: Cases from Turkey, *Journal of Management in Engineering*, 31(**6**), 050150021-050150029.

Bond, S (2010) Lessons from the leaders of green designed commercial buildings in Australia, *Pacific Rim Property Research Journal*, 16(**3**), 314-338.

British Standard Institution (2008) Buildings and Constructed Assets-Service Life Planning-Part 5: Life Cycle Costing, BS ISO 15686-5:2008. London: BSI.

Chidiac, S E, Catania, E J C, Morofsky E and Foo, S (2011) Effectiveness of single and multiple energy retrofit measures on the energy consumption of office buildings, *Energy*, 36, 5037-5052.

Dascalaki, E and Santamouris, M (2002) On the potential of retrofitting scenarios for offices, *Building and Environment*, 37, 557-567.

Davies, P and Osmani, M (2011) Low carbon housing refurbishment challenges and incentives: Architects' perspectives, *Building Environment*, 46(**8**), 1691-1698.

Du Plessis, C (2007) A strategic framework for sustainable construction developing countries, *Construction Management and Economics*, 25, 67-76.

Fasna, M F F and Gunatilake, S (2018) Factors affecting the successful adoption and implementation of energy retrofits in existing hotel buildings, *In:* Y G Sandanayake, S Gunatilake, and K G A S Waidyasekara (Eds.) *7th World Construction Symposium*, 29 June - 1 July 2018, Colombo, Ceylon Institute of Builders, 244-256.

Fluhrer, C, Maurer, E and Deshmukh, A (2010) Achieving radically energy efficient retrofits: The Empire State Building example, *ASHRAE Transactions*, 116 (Part 2), 236-243.

Karunaratne, T L W and De Silva, N (2019) Demand-side energy retrofit potential in existing office buildings, *Built Environment Project and Asset Management*, 9(**3**), 426-439.

Kasivisvanathan, H, Ng, R T L, Tay, D H S and Ng, D K S (2012) Fuzzy optimisation for retrofitting a palm oil mill into a sustainable palm oil-based integrated bio refinery, *Chemical Engineering Journal*, 200, 694-709.

Liang, X, Peng, Y and Shen, G Q (2016) A game theory-based analysis of decision making for green retrofit under different occupancy types, *Journal of Cleaner Production*, 137, 1300-1312.

Love, P and Bullen, P A (2009) Towards the sustainable adaptation of existing facilities, *Facilities*, 27(**9/10**), 357-67.

Mahlia, T M I, Said, M F M, Masjuki, H H and Tamjis M R (2005) Cost-benefit analysis and emission reduction of lighting retrofits in residential sector, *Energy and Buildings*, 37, 573-578.

McDonald, C, Ivery, S and Gagne C M (2008) *ACEEE Summer Study on Energy Efficiency in Buildings*, Asilomar Conference Grounds, August 12, 2018 to August 17, Pacific Grove, CA.

McGraw-Hill Construction (2009) *Green Building Retrofit and Renovation Rapidly Expanding Market Opportunities Through Existing Buildings*. New York.

Miller, E and Buys, L (2008) Retrofitting commercial office buildings for sustainability: Tenants' perspectives, *Journal of Property Investment Finance*, 26(**6**), 552-61.

Rehm, M and Ade, R (2013) Construction costs comparison between green and Conventional office buildings, *Building Research and Information*, 41, 198-208.

Township's Boards of Historical and Architecture Review (2008) *Historic Preservation and Sustainability*. Pennsylvania: CHRS Inc of North Wales.

United States Green Building Council (2003) *Building Momentum: National Trends and Prospects for High Performance Green Buildings*. Washington, DC: United States Green Building Council.

Weerasinghe, A S and Ramachandra, T (2018) Economic sustainability of green buildings: A comparative analysis of green vs non-green, B*uilt Environment Project and Asset Management*, 8(**5**), 528-543.

Wilkinson, S J, James, K and Reed, R (2009) Using building adaptation to deliver sustainability in Australia, *Structural Survey*, 27(**1**), 46-61.

Zhai, X, Reed, R and Mills, A (2014) Addressing sustainable challenges in China: The contribution of off-site industrialisation, *Smart and Sustainable Built Environment*, 3(**3**), 261-274.

MAPPING EMERGING SUBCONTRACTING NETWORKS FOR THE ENERGY EFFICIENCY RETROFIT OF HARD-TO-TREAT BUILDINGS

Henry Myers, Faye Wade[1] and Janette Webb

Heat and the City Team, University of Edinburgh, Chisholm House, High School Yards, Edinburgh, EH1 1LZ, UK

The Energy Efficient Scotland Programme is the Scottish Government's flagship programme for improving the energy efficiency of every building in Scotland. This Programme represents an unprecedented effort to retrofit the entire Scottish building stock, but mixed-use urban buildings offer a particular challenge. Energy Efficient Scotland will run over the next 15-20 years and its delivery is critical for achieving ambitious targets to reduce emissions by 23% and 59% from domestic and non-domestic buildings, respectively, by 2032. Actors from across private, public, and civic sectors are critical for retrofit delivery. However, the contractual relationships, communication, and trust networks in place for energy retrofitting are currently unknown. Understanding of these supply chains is essential for identifying where responsibility lies for different activities, particularly in buildings of mixed-ownership. Consequently, this paper combines Social Network Analysis and qualitative interview data to explore communication and trust amongst an emerging supply chain for a retrofit project in a hard-to-treat mixed-use building. The results show that contractual, communication, and trust networks do not always overlap, with actors in influential roles carrying less risk, for example This provides critical understandings for policy makers seeking to develop clear guidance for roles and responsibilities of different actors involved in the delivery of national-scale energy retrofit.

Keywords: retrofit, social network analysis, local government, social capital

INTRODUCTION

Energy Efficient Scotland (EES) is the Scottish Government's flagship programme for increasing the energy efficiency of all buildings in Scotland (Scottish Government, 2018). This is critical for meeting the combined goals of reducing fuel poverty and meeting the ambitious target to reduce greenhouse gas emissions by 90% of 1990 levels, by 2050, set out by the 2018 Scottish Climate Change Bill. The success of Energy Efficient Scotland is reliant on the coordination of supply chain actors that will manage and deliver Energy Efficient Retrofit Services (EERS) on an unprecedented scale.

Following limited action on retrofitting to date, and the failure of the UK Government's Green Deal retrofitting programme (Rosenow and Eyre, 2016), there are serious questions concerning the factors that constrain or facilitate EERS diffusion at scale. Prior research has highlighted the need for greater innovation and integration

[1] faye.wade@ed.ac.uk

Myers, H, Wade, F and Webb, J (2019) Mapping Emerging Subcontracting Networks for the Energy Efficiency Retrofit of Hard-to-Treat Buildings *In:* Gorse, C and Neilson, C J (Eds) *Proceedings of the 35th Annual ARCOM Conference,* 2-4 September 2019, Leeds, UK, Association of Researchers in Construction Management, 852-861.

throughout construction supply chains. However, little is known about how supply chain actors are actually creating project teams to deliver EERS.

This paper presents exploratory research which identifies the supply chain actors emerging for the delivery of EERS and the conditions that influence the success or failure of retrofit projects. It employs the concept of social capital alongside Social Network Analysis (SNA) to interrogate how supply chain actors negotiate network integration and innovation. Through this, we pilot a research model that explores the different types of tie in place for complex energy retrofitting. These include contractual, communication, and trust ties, and interrogation of how these ties overlap.

LITERATURE REVIEW

Reluctance for Building Retrofitting in the UK Construction Sector

The UK construction sector has long been characterised as fractured, adversarial, and innovation-averse, posing serious challenges for complex and innovative energy retrofitting projects (Pryke, 2012; Larsen, 2011; Latham, 1994). The Farmer Review (2016) identifies structural fragmentation, ambiguity in project planning, and lack of collaboration as some of the critical symptoms of poor performance in the UK construction industry. However, these challenges continue to be overlooked in the development of policy for energy retrofitting. In particular, the UK Government's Green Deal, which aimed to encourage adoption of energy efficiency measures by domestic householders, was cancelled in 2015 after achieving only .03% of the projected adoption rate over 2.5 years (Rosenow and Eyre, 2016). Failure of the Green Deal was attributed to an over-reliance on financing models while neglecting social factors, especially supply chains (Fuller, 2010; Rosenow and Eyre, 2016; BEIS, 2018).

Energy Efficient Scotland exists within an emerging and ambiguous market; it's success will rely on high levels of supply chain innovation and integration. EES faces several challenges owing to organisational, resource, and task complexities, coupled with uncertainties and the necessity for innovation in EERS projects (Moore *et al.,* 2018; Papadonikolaki *et al.,* 2017). Critically, whole-building approaches to EERS are recommended over isolated installations due to the interdependent nature of effects from EERS interventions (for example an upgraded heating system may not deliver potential energy savings if followed at a later date by additional insulation). However, a report on retrofit supply chain coordination by the department for Business Energy and Industrial Strategy highlights that "[whole house retrofit] requires coordination across trades … that the workforce is not equipped to deliver," (BEIS, 2018: 11). Thus, understanding how supply chain actors negotiate project relationships to facilitate (or fail to facilitate) integration and innovation needs to be a priority for further policy aiming to deliver energy efficient retrofitting.

Networks for Innovation in Construction

Supply chain complexity can be defined as the "number of transacting actors, extent of inter-relationship among actors, degree of differentiation among them in terms of practices and also their frequency of interaction" (Chakraborty, 2015: 4). Complexity is problematic in emerging markets, such as EERS, because accompanying uncertainty and risk may lead to increased transaction costs (the costs related to operational procedures and organisational processes which can rise proportionally to project complexity) (Moore *et al.,* 2018). Transaction costs can account for as much as 30% of EERS costs. This can inhibit delivering EERS at scale due to reduced

profit margins and increased investment risk associated with ambiguous markets and newer technologies (Moore *et al.,* 2018; Gooding and Gul, 2016). Several strategies have been implemented to mitigate this through the integration of construction supply chains. These include Supply Chain Management (SCM) and the New Engineering Contract (NEC3), which seek to facilitate greater cooperation and risk sharing amongst supply chain actors through formal contractual arrangements. Despite these, the generation of trust in construction supply chains can prove difficult due to their temporary nature (Meyerson *et al.,* 1996). In temporary networks characterised by high interdependence, actors must engage in "swift trust" (Meyerson *et al.,* 1996) to reduce uncertainty and risk. Actors who are positioned at critical junctures of communication and interaction may influence whether or not swift trust is generated in projects (ibid; Boddy *et al.,* 2010; Iturrioz *et al.,* 2014). Literature has increasingly recognised the critical role of informal relationships and social capital in facilitating supply chain integration while mitigating negative aspects of complexity in nascent and ambiguous project settings (Wichmann and Kaufmann, 2015).

Bonding and Bridging Social Capital in Supply Chain Networks

Social capital refers to the capacity and assets inhering in social networks by virtue of intersubjective relationships; these assets can be called upon by actors for both individual and collective benefits. Social capital can be categorised as bonding or bridging capital. Bonding capital (also referred to as strong ties) refers to social capital produced in dense groups where homogenous actors share many of the same mutual connections. Bridging capital (also known as weak ties or brokerage) refers to social ties that connect otherwise disconnected, distinct groups (Granovetter, 1973).

Bonding capital is generally understood to increase performance of supply chains due to its positive impact on interorganisational communication, trust, and alignment of goals and interests (Chinowsky *et al.,* 2008; Koh *et al.,* 2016). Densely bonded supply chain networks are also thought to be better equipped to mitigate risk and agilely coordinate adaptive responses to unforeseen circumstances in complex projects (Moore *et al.,* 2018). However, the role that bridging capital has on supply chains is more uncertain. Bridging capital is considered to be critical for innovation as it is thought to introduce new ideas and resources into groups and help coordinate otherwise siloed workgroups in organisational settings (Granovetter, 1973). However, empirical studies on construction supply chains find that the presence of network brokers (or bridges) fails to increase supply chain coordination, performance, and innovation (Carnovale and Yeniyurt, 2015; Larsen, 2011). Brokers can also present challenges including the bottlenecking of flows of relevant information (Borgatti and Li, 2009), and having the capacity to influence networks in opportunistic ways (ibid). Consequently, this research critically examines the role of network brokers in the delivery of EERS in a hard-to-treat mixed-use building. To do this, it applies qualitative interviews and Social Network Analysis; these are detailed in the following section.

METHOD

The Case Study Project

This research uses a case study of EERS on a hard-to-treat listed building of mixed-occupancy, including both domestic and non-domestic properties. This project is taking place under the Energy Efficient Scotland programme, through which Scottish Government provide funding for local authorities to coordinate retrofitting projects.

Local authorities contribute to the selection of properties for the pilots, and the design and procurement of the works taking place. The case study building has 12 residential properties in the block: six of these are holiday lets, three are long-term rentals, two are owner-occupied, and one is vacant. There are also two commercial properties. This is a listed building, wherein the council lacks authority to intervene on behalf of property owners. This project represents the complexity of both stakeholder interests and diverse skills in the supply chain; understanding these issues at this site has wider implications for the development of EERS supply chains. The case selection was also influenced by the willingness of stakeholders and supply chain actors to participate in the study. The researchers are aware of the Hawthorne effect, particularly that participants associated with the project may perceive the research as an opportunity to narrate and advocate for their position amidst various and sometimes competing interests. Evidence has been triangulated across documentary and verbal sources, and this has been considered in the selection and presentation of data. This is an active project; all actors and organisations have been anonymised in the presentation of data.

This paper focuses on the relationships between three central actors: the association of property owners for the building (the Project Client); the administrator of grant funds (the Administrator); and the lead architect (the Project Lead). The project proposal was submitted jointly by the local authority and the Administrator. The Administrator then held responsibility for managing the grant funds and monitoring project activities. They also instituted an owner's association as the Project Client, a legal entity with authority to make decisions on behalf of the building's property owners. The property owners are themselves heterogeneous, with differing interests and goals. As the Project Lead, the architect manages the contractual relationships for all other contracted work and provides the majority of project management duties.

Social Network Analysis Incorporating Quantitative and Qualitative Approaches

Social Network Analysis (SNA) is an approach for measuring and analysing social networks and social capital that is quickly gaining prominence in construction and supply chain management literature (Wichmann and Kaufmann, 2015). SNA utilises graph theory to plot relationships (ties) amongst actors (nodes) in a network (Scott, 2017). Mathematical formulae then allow for the quantitative analysis of social capital inhering in these networks. SNA has been used throughout construction sector research, most prominently to examine formal contractual ties between organisations in project-based supply chains, and levels of influence or stakeholder salience derived from those (Wichmann and Kaufmann, 2015; Pryke 2012; Mok and Shen, 2016; Aaltonen and Sivonen, 2009). However, SNA is increasingly used to examine informal ties to explore how structural, cognitive, and relational forms of social capital intersect with formal contractual ties. This is particularly useful for understanding how formal and informal ties influence construction networks and identifying the conditions for project success (Papadonikolaki *et al.,* 2017). However, while SNA provides a perspective of ways in which the structure of social relations impacts actor behaviours, constraints, and opportunities, it provides relatively little insight into the content of these relationships (Crossley, 2010). Consequently, we employ a mixed-methods qualitative SNA approach (Crossley, 2010), incorporating participant insights through qualitative interviews.

Data Collection and Analysis

We examine two types of network ties amongst project stakeholders (communication and trust ties). Data collection followed a snowball sampling approach, beginning

with the local authority and the Administrator, through whom we identified the Project Lead and the Project Client, along with remaining members of the design team and subcontractors. Semi-structured interviews included directed questions to elicit network data on contractual and communication ties, and issues of trust, which have been identified as salient to bonding and bridging capital (e.g. Pryke, 2012). The interviews also included open queries that allowed for probing of respondent-identified issues. The interviews lasted approximately one hour, they were transcribed and then coded using Atlas.ti. This process identified approximately 75 salient codes; of these, issues of communication, interest alignment, trust, transparency, and risk were selected as significant for the development of this network.

Adhering to guidance for deriving network data from qualitative data sources (Crossley, 2010), we interpreted interfirm communication on a four-point scale:

0 = no communication;
1 = communication channel present but infrequently used;
2 = semi-regular communication, e.g. progress meetings;
3 = regular or intense communication.

Trust was interpreted on a binary scale (0 = actor dyads fail to express a trusting relationship; 1 = actor dyads express a mutual level of trust). Contractual ties did not require qualitative interpretation and were assigned binary values. All communication ties were symmetrical and trust ties only show mutual responses based on the understanding that the benefits of trust are only engendered when mutually shared. Network measures of density and betweenness centrality were used to describe structural qualities of network cohesion and actor influence respectively for each type of tie. We used three SNA measures to examine structural features of the project network (density, degree centrality, and betweenness centrality).

Density is a global measure of how cohesive a network is, expressed as the proportion of actual ties to possible ties amongst all actors in a network. Possible density measures range between 0 (no ties existing amongst network actors) to 1 (all actors are tied to all other actors); measures over 0.5 are generally considered dense and under 0.1 are considered not dense. Density in communication and trust networks has been widely shown to have positive effects on construction supply chain performance (Larsen, 2011; Moore *et al.,* 2018). In this study, density of communication and trust networks is compared to examine whether communication leads to trust on a network level (Chinowsky *et al.,* 2008). Degree centrality is a node-level measure indicating the influence of an organisation on a network as expressed through its prominence. It is measured through the number of ties connecting to a node. This study measures the degree centrality of trust networks to identify organisations perceived by others as trustworthy or untrustworthy. Betweenness centrality is a node-level measure of network brokerage, expressed as a node's presence on the shortest path between other nodes. Like bridging social capital, the role of betweenness on construction supply chains is still ambiguous (Borgatti and Li, 2009; Carnovale and Yeniyurt, 2015). In this study, betweenness is measured for communication ties in order to examine which actors are influential in shaping information flows in the networks. Communication betweenness centrality is compared to trust degree centrality to examine the relationship between communication brokerage and trustworthiness. Qualitative analysis is applied to interrogate the content of ties and identify ways that brokering roles may promote or constrain network trust.

RESULTS

Describing the EERs Project Network

Figure 1: Map illustrating communication ties. Larger node size illustrates larger betweenness centrality. Thicker lines illustrate stronger communication.

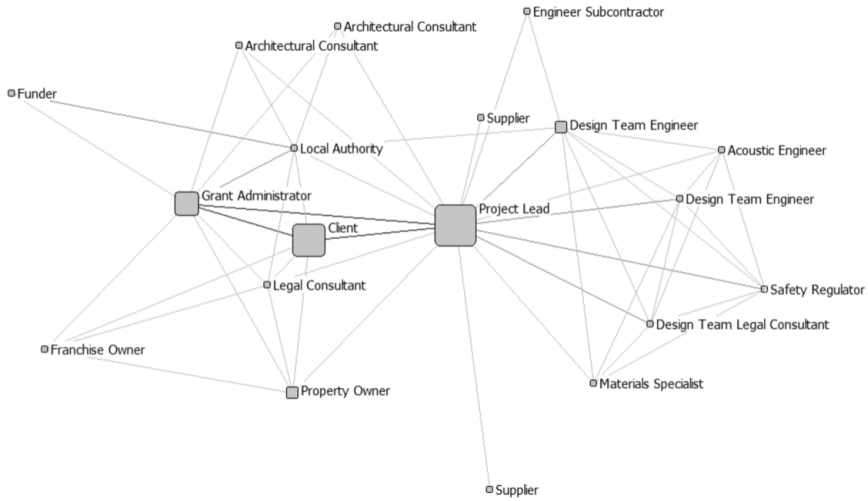
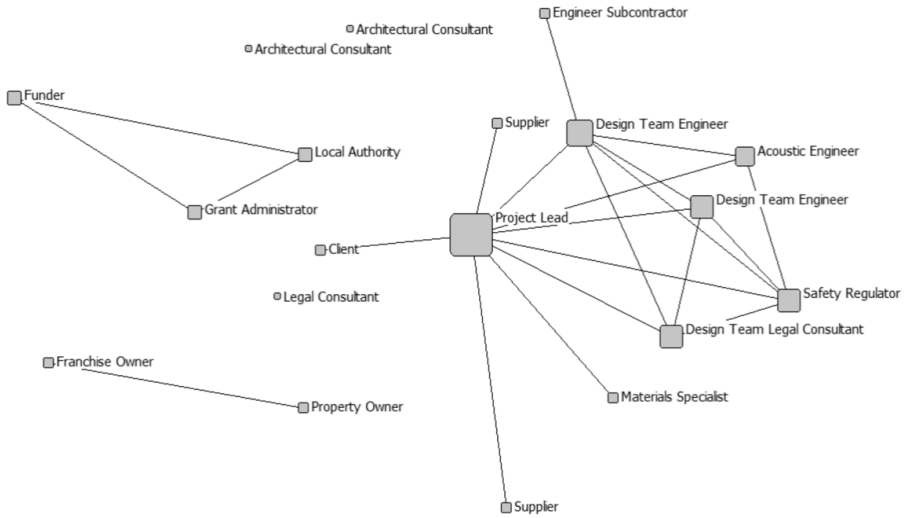


Figure 2: Map illustrating trust ties. Larger node size illustrates larger normalised degree centrality.



Measurement of communication channels and trust ties in the case study project reveals a moderate density in communication networks (0.334 - Figure 1), but a weak density in trust ties (0.123 - Figure 2). Discrepancy between densities suggests that communication has not uniformly matured into trust amongst project actors. Lack of trust amongst key stakeholders, namely the Client and the Administrator, may indicate a potential problem for coordination of ongoing project activities. The Project Client, Administrator, and Project Lead are clearly identifiable as the most prominent nodes in the network illustrated in Figures 1 and 2. Of these three, we observe the highest betweenness and degree centrality for the Project Lead on both communication and trust networks respectively. They thus act as a nexus of influence and control, acting as both a hub for project coordination and a broker for information between various stakeholders. Meanwhile the Administrator and Client have high communication betweenness but low degrees of trust, notably between each other. The following data

investigates the differences between these relationships and their possible impact on the project.

Betweenness Centrality and Brokering Relationships

Shared interests and transparency for developing trust
Central actors that share a large burden of risk, or have "skin in the game," are more likely to generate trust amongst others, especially those with whom they share risk. The Project Lead occupies the greatest communication brokerage role (normalised betweenness = 72.876). They also have the highest normalised degree centrality for trust (0.5), with trust between the Client and the Project Lead being especially noteworthy. This trust was particularly apparent during an interview with the Client representative:

> [The] Architects I'm entirely comfortable with… [they] have got such a huge stake in this in terms of future business and potential bad reputation if it doesn't go well so I could relax and I'm confident… [The Architect] stand[s] to make a fortune from this project, they're getting experience here in areas that no one else has got experience on (Client representative).

This echoes Chinowsky et al.'s (2008) assertion that communication exchange that focuses on building mutual understanding of the interests, constraints, and processes of different stakeholders helps facilitate trust. This also supports the overall capacity of actors to act cooperatively and with agility in uncertain and high-risk environments, like the hard-to-treat building studied here. In this case, the recognition of mutually aligned interests relates to perception of fair distribution of contractual risk. At another point in our interview, the Client Representative noted that: "you look at the risks, you look at the liability of the parties involved and […] if you recognise that the supplier has a vested interest then you don't need to make the contracts a problem".

Divergent interests and obscurity for diminishing trust
Actors with a high degree of centrality (and hence, influence) but who are risk averse appear less trustworthy. It is less problematic if actors with low centrality share little risk, as seen in the case of a subcontracted member of the design team who acts as a mechanical engineering consultant. Complexities and problems arising from the project have very little impact on the costs or reputation of the mechanical engineer, relative to those of the client and the project lead. However, because the mechanical engineer has only a peripheral centrality (contractual and communication betweenness centrality = 0), their lack of investment has a low influence on the overall trust and integration of the network. In contrast to this, the Administrator has high normalised betweenness (34.641), but a low normalised degree of trust (0.111), most remarkably in their relationship with the Client and with the Project Lead. At interview the Client explained some of the challenges of working with the Administrator:

> [The Administrator] is a different kind of beast and so I'm a bit less comfortable with them and there's a bit of antagonism's maybe too strong a word but concern...a number of the owners and the wording of this constitutive deed - they find the terms very onerous (Client representative)

While the client highlighted the lack of interest alignment and risk sharing by the Administrator, the Project Lead reported that the Administrator's lack of transparency hampers their capacity to coordinate the rest of the network:

> And at that point we didn't think there was scope to shift the programme because […] we've never seen or we've never been involved in any discussions with Scottish Government or the Council or the Administrator […] and we haven't seen their original funding application […] I really felt that the Administrator as the kind of the well not

> technically the grantee but the, as the project officers on this one […] they had someone who could say right well we could do this and that could kind of mitigate the impact on the project (Project Architect)

However, the Administrator, whose role it is to oversee that contracted works coincide with the dictates of the grant, expressed concern that owners often lack an understanding of the structure of the grant process: "for the [Client] you know, it's a different world and it's difficult to challenge […] what you are being told if you are not in the sector […]." These challenges to the Client's interests, while necessary for the management of the grant, are not always understood by the Client or the Project Lead, because neither of these have ever seen the original terms of the grant. As such, while stakeholders appreciated the role that the Administrator played in initially setting up the Client as a legal entity so that it could represent itself in contracts management, it appears that stakeholders are unclear on the role that the Administrator continues to play. They report that it feels like they introduce unnecessary complexity which in turn ends up increasing the transaction costs of the project and the costs incurred by the other stakeholders. Both the Project Lead and the Client expressed a desire to have more direct contact with the funders in order to understand more clearly the terms, and subsequently move forward with the coordination of works. There was also a view that the Administrator bottlenecks capacity to flexibly manoeuvre in response to complex and dynamic issues in the property itself, the Client's demands, and the rest of the supply chain.

DISCUSSION

While network brokerage is known to have some impact on supply chain cohesion (Iturrioz *et al.,* 2014; Boddy *et al.,* 2010), little is known about why some forms of brokerage facilitate cohesion, while others diminish it. This research seeks to address that gap. It builds on previous recognition that strong communication networks are critical to the formation and performance of teams for the delivery of innovative construction projects such as EERS (Chinowsky *et al.,* 2008; Larson, 2011). Focusing on the delivery of retrofit in a hard-to-treat mixed-use listed building, this study has interrogated the specific ways that actors occupying a brokering position facilitate supply chain integration and innovation. In agreement with Chinowsky *et al.,* (2008), we found that communication channels may or may not give rise to specific types of knowledge sharing that facilitate trust and goal alignment. These are necessary informal social capital resources that allow for network integration.

In this case, the Administrator held a high degree of betweenness centrality in both contractual and communication networks, but a low degree of trust. Meanwhile the Project Lead held the highest degree of betweeness centrality in contractual and communication networks, and highest degree centrality for trust. Trust amongst these central actors varies based on the intensity and frequency of communication, the transparency of communication, and the perception of mutually shared interests and shared risk. This is critical for the delivery of a programme like Energy Efficient Scotland, the success of which is reliant on retrofitting action taking place in all property types, including mixed-use, mixed-ownership buildings like that discussed herein.

The EES Programme is built on a model of local authority oversight of retrofitting projects. However, local authorities do not have the power to intervene in the management of privately-owned properties. In this case, the funding structure incorporated the choice to outsource grant management duties to an Administrator and

included the legal incorporation of property owners into a representative body responsible for decision making. This structure may infuse administrative organisations with a high degree of influence over the project, but unequal distributions of risk. This may hamper the capacity of the network to form cohesion and flexibly manoeuvre in the face of ambiguous and complex work environments.

CONCLUSION

This research has direct implications for policy approaches to the rollout of energy efficiency retrofitting programmes. The differing structures of communication and trust networks revealed here demonstrates the need for policy makers to develop clear guidance for the identification of roles and responsibilities for the different actors recruited into the delivery of complex retrofitting projects. The research presented herein is a preliminary look at the supply chain networks emerging for the delivery of building retrofitting. Further work is required to identify the variety of contractual networks emerging for different types of projects, for example, whether there are distinctions when project management is retained in-house by local authorities.

REFERENCES

Aaltonen, K and Sivonen, R (2009) Response strategies to stakeholder pressures in global projects, *International Journal of Project Management*, 27, 131-141.

Boddy, S, Rezgui, Y, Cooper, G and Wetherill, M (2010) Activity awareness as an enabler for communication and network building in construction design teams, *Journal of Computing in Civil Engineering*, 24(**5**), 430-450.

Borgatti, S and Li, X (2009) On social network analysis in a supply chain context, *Journal of Supply Chain Management*, 45(**2**), 5-22.

Carnovale, S and Yeniyurt, S (2015) The role of ego network structure in facilitating ego network innovations, *Journal of Supply Chain Management*, 51(**2**), 22-46.

Chakraborty, S (2015) Linking supply chain network complexity to interdependence and risk-assessment: Scale development and empirical investigation, *Business: Theory and Practice*, 17(**1**) 1-12.

Chinowsky, P, Diekmann, J and Galotti, V (2008) Social network model of construction, *Journal of Construction Engineering and Management*, 134(**10**), 804-812.

Crossley, N (2010) The social world of the network: Combining qualitative and quantitative elements in social network analysis, *Sociologic*a, 1, 1-34.

Department for Business, Energy and Industrial Strategy (2018) *Grant to Support to Coordinate the Supply Chain for Retrofit at a Local Level*. London: Department for Business, Energy and Industrial Strategy.

Farmer, M (2016) *The Farmer Review of the UK Construction Labour Model*. London: Construction Leadership Council.

Fuller, M (2010) *Driving Demand for Home Energy Improvements: Motivating Residential Customers to Invest in Comprehensive Upgrades That Eliminate Energy Waste, Avoid High Bills and Spur the Economy.* Environmental Energy Technologies Division: Lawrence Berkeley National Laboratory.

Gooding, L and Gul, M (2016) Energy efficiency retrofitting services supply chains: A review of evolving demands from housing policy, *Energy Strategy Reviews*, 11(**12**), 26-40.

Granovetter, M (1973) The strength of weak ties, *American Journal of Sociology*, 78(**6**), 1360-1380.

Iturrioz, C, Aragon, C and Narvaiza, L (2014) How to foster innovation within SMEs' networks: Social capital and the role of intermediaries, *European Management Journal*, 33(2015), 104-115.

Koh, T Y, Rowlinson, S, Tuuli, M M (2012) Social capital and construction project management: A vignette and theoretical framework, *Joint CIB International Symposium*, Rotterdam, Netherlands.

Larsen, G D (2011) Understanding the early stages of the innovation diffusion process: Awareness, influence and communication networks, Construction Management and Economics, 29(**10**), 987-1002.

Latham, M (1994) *Constructing the Team - Joint Review of Procurement and Contractual Arrangements in the United Kingdom Construction Industry*. HMSO.

Mok, M K Y and Shen, G Q (2016) A network-theory based model for stakeholder analysis in major construction projects, *Procedia Engineering*, 164, 292-298.

Moore, C B, Payne, G T, Autry, C W and Griffis, S E (2018) project complexity and bonding social capital in network organizations, *Group and Organization Management*, 43(**6**), 936-970.

Papadonikolaki, E, Verbraeck, A and Wamelink, H (2017) Formal and informal relations within bim-enabled supply chain partnerships, *Construction Management and Economics*, 35(**8-9**), 531-552.

Pryke, S (2012) *Social Network Analysis in Construction*. Chichester, West Sussex: Wiley.

Ratajczak-Mrozek, M and Malys, L (2011) Formal and informal cooperation within supply chains and company performance, *In*: *27th IMP Conference: The Impact of Globalization on Networks and Relationship Dynamics*. Glasgow, UK.

Rosenow, J and Eyre, N (2016) A post mortem of the Green Deal: Austerity, energy efficiency and failure in British energy policy, *Energy Research and Social Science*, 21, 141-144.

Scott, J (2017) *Social Network Analysis*. Los Angeles: Sage.

Scottish Government (2018) *Energy Efficient Scotland: Routemap*. Available from Https://www.gov.scot/publications/energy-efficient-scotland-route-map/ [Accessed 19/07/2019].

Wichmann, B K and Kaufmann, L (2016) Social network analysis in supply chain management research, I*nternational Journal of Physical Distribution and Logistics Management,* 46(**8**) 740-762.

RISK MANAGEMENT

RISK ASSESSMENT AND RISK ENGAGEMENT IN THE CONSTRUCTION INDUSTRY WITHIN CONFLICT ZONES

Bahaa Razia[1], Peter Larkham[2] and Niraj Thurairajah[3]

[1&2]*School of Engineering and the Built Environment, Birmingham City University, Birmingham, United Kingdom, Bartholomew Row, B5 5JU, UK*

[3]*Architecture and Built Environment, Northumbria University, Sutherland Building, Newcastle-Upon-Tyne, NE1 8ST, UK*

Stakeholders throughout the construction industry deal with risks and uncertainties, which are particularly important where they lead to poor construction development. Very few studies have examined stakeholders` perception of risk in the construction industry especially in conflict zones. However, it is important to identify how risk is perceived and dealt with effectively in order to successfully implement different strategies of dealing with risks. To achieve this, an initial framework is developed from current practices, applied and then refined based on the data gathered. Data collection has been carried out in Palestine using semi structured qualitative interview. A range of risk variables were uncovered, including movement restrictions, limitations in the locations of construction and problems related to specific governmental policies. The findings also confirmed the significant influence of some existing theories: cultural, social and psychometric, and revealed others including the process of policy implementation and validation. The interviewees considered that risks relating to inappropriate implementation of policies is the main cause of poor achievement of construction development, followed by restrictions in movement and poor land management. Therefore, there is a need to provide stakeholders and policymakers with better knowledge of how risk is perceived and dealt with in order to enhance construction development in these risky locations.

Keywords: risk perception, risk engagement, conflict zones

INTRODUCTION

Achieving sustainable development in the construction industry is a vital factor affecting the environment, social and economic sectors (Brennan and Cotgrave, 2014; Akadiri and Fadiya, 2013). Current practises demonstrate various factors that affect construction development including cost, risk, lack of information and communication (Rostami and Thomson, 2017). In conflict zones, different factors and problems affect achieving sustainable development compared with non-conflict zones (Enshassi, 2005). These factors include financial constraints, lack of understanding the development concept and inadequate institutional structure. Despite the focus of existing studies on delivering potential development for the construction industry in conflict and non-conflict zones, there is little research that considers identifying how stakeholders shape their perceptions and respond to risk variables, especially in the

[1] bahaa.razia@mail.bcu.ac.uk

Razia, B, Larkham, P and Thurairajah, N (2019) Risk Assessment and Risk Engagement in the Construction Industry Within Conflict Zones *In:* Gorse, C and Neilson, C J (Eds) *Proceedings of the 35th Annual ARCOM Conference,* 2-4 September 2019, Leeds, UK, Association of Researchers in Construction Management, 863-872.

context of the construction industry within conflict zones. The application of risk perception and its related aspects provides the opportunity to deal with risks in the construction industry effectively in order to achieve the desired development. Identifying the factors that affect how stakeholders construct their perceptions assists in providing better knowledge and useful information regarding particular risk events. Therefore, this paper reviews different approaches of risk perception and its relevant aspects together with analysing how they can be implemented in order to achieve sustainable development in the construction industry in conflict zones. It will identify the significant relationship between risk perception and construction development through multiple stakeholders` perspectives. The paper explores different views of participants and current practices in order to contribute to the existing knowledge of risk perception.

Background to Risk Perception

Because little has been written about the application of risk perception to construction, this paper begins by considering this and particularly its application to the construction industry within conflict zones. Risk perception is defined as the subjective decision or assessment that people make to describe a particular risk events and its consequences (Sjoberg *et al.,* 2004). Risk perception is conceptually different from the objective aspects of risk that can be evaluated and measured using naturalist models of risk assessment (Jasanoff, 1998). Wogalter *et al.,* (1999) presented a general concept of risk perception and defined it as a broad notion of awareness and knowledge regarding particular risk, and likelihoods of consequences of a situation that may lead to potential harm. Examining risk perception is related to two main approaches. These are the cultural approach which was developed by Douglas and Wildavsky (1982), and the psychometric approach. The psychometric approach has dominated risk perception studies during recent decades (Slovic, 2000). It takes into consideration both qualitative and subjective aspects (Slovic, 1992). This approach assumes that risk perception is considered as multidimensional and can be evaluated by identifying the unique features regarding a particular risk resource. Fischhoff *et al.,* (1978) claimed that risk factor analysis revealed that there are unique characteristics for risk sources and these characteristics affect the way in which risk is perceived. Nine different factors were found to have a significant effect on risk perception and its resources. These include knowledge about the risk by the individuals who are exposed to that potential risk, voluntariness of risks, control over the risk, knowledge about risk in literature (science), old or new risk (familiarity), catastrophic levels of risk (a risk that may affect just one person at a time or affect groups or large number of individuals at once), common or dread risk (a risk that can be managed and accepted calmly by people or a risk that people dread), severity of consequences and immediacy of effect (Fischhoff *et al.,* 2000). Familiarity and dread were found to be the most important dimensions that need to be considered in examining risk perception.

The cultural approach also plays an important role in risk perception and its related aspects (Wildavsky and Dake, 1990). Douglas and Wildavsky (1982) developed four approaches to represent cultural theory including grid/group arrangement. Each approach relates to particular outlook of risk and specific social aspect. Grid refers to the degree to which individuals are restricted and constrained in their social role. In this category, tighter binding and social restriction bounds people control and their negotiations. The group approach refers to the extent to which people are restricted by feelings. More restrictions lead people to engage less with social events and have

less control on their personal decisions. Grid/group approaches include four categories: Individualist, Fatalist, Hierarchical and Egalitarian (Marris *et al.,* 1998). However, several studies exploring risk perception and applying the cultural theory measurements have failed to address the findings of Wildavsky and Dake (Marris *et al.,* 1998; Peters and Slovic, 1996; Oltedal and Rundmo, 2007). As with the psychological approach of risk perception, although the cultural approach has provided beneficial understandings into risk perception and its related aspects, limitations are evident. The cultural theory is based on hypothetical rather than empirical evidence (Hirsch and Baxter, 2011). Furthermore, Williamson and Weyman (2005) argued that the four categories of cultural theory provide a mobility (changeable) concepts. For instance, an individual's opinion regarding a particular situation is not constant and may change over time due to various factors such as personal, beliefs, values social identify or situation (Vandermoere, 2008). The lack of interaction between these categories leads to polarised perspective of people`s opinions and fails to address the real perceptions of individuals and their possible actions. Therefore, Gaskell and Allum (2011) argued that risk perception should be considered as a subjective and socially constructed aspect, and that individuals are ambivalent with uncertain feelings and ideas regarding particular situations.

Relevant Aspects of Risk Perception

There are also different aspects that affect how risk is perceived and deal with. Uncertainty plays a vital role in constructing individuals' opinions, particularly in unpredictable, complex or ambiguous conditions, when people experience certain risks and are uncertain about their expectations or knowledge (Brashers, 2001). Moreover, uncertainty is associated with aspects that have a significant effect on the way that individuals respond to risks and make decisions (Powell *et al.,* 2007). For instance, when individuals are insecure about a risk event, they shape their thoughts and evaluate risks based on their own subjective perceptions. For this reason, Renn (2004) claimed that people`s perception of certain risks is strongly affected by the availability of data about risks, the source of these data and the approaches that are adopted to explain and interpret it.

In terms of conformability, Cook and Bellis (2001) emphasised that individuals are capable of tolerating and dealing with risk events when they make their own decision using their own choices whether to engage or not with certain risks. This usually occurs when individuals are able to deal with risk and its possible consequences using their knowledge and experience (Sjoberg *et al.,* 2004). However, even if the risk is controlled and dealt with, individuals sometimes have either negative or positive reactions when they are involved in a specific risk situation. As an example, car drivers believe that the possibility of being involved in a car accident and exposed to possible risks is low when they are driving as they have the ability to control the vehicle and make their own informed decisions: nevertheless they believe that the likelihood of exposure to the same risk is relatively high when they are passengers and do not have the ability to make decisions (Sjoberg *et al.,* 2004). Kos and Clarke (2001) argued that some people often amplify the idea of dealing with risks, as they believe that they have greater abilities and skills to deal with risks compared with others. Familiarity is also one of the wide range of aspects that influence how people shape their perceptions (Paek *et al.,* 2016). The term familiarity is defined as the details and information about particular risk situations known by the affected individuals (Schmidt, 2004). Furthermore, when the situation is familiar to people, they usually perceive fewer risks and feel safer regarding this situation. It is argued

that individuals are often less concerned about risk and its consequences when the situation is familiar to them (Slovic, 2000; Fragouli and Theodoulou, 2015). In addition, high levels of awareness among individual's leads to increase in their familiarity about certain risks, consequently the likelihood occurrence of risk and its consequences become minimised (Schmidt, 2004). Klein *et al.,* (2010) claimed that individuals who are familiar with certain risk circumstances, are likely avoid following any protective or preventive considerations in order to deal with that risk. Although familiarity with risk has a significant influence in decreasing risk perception, individuals sometimes have a heightened sense of risk even if the risk situation is familiar to them (Brody *et al.,* 2008).

Risk Perception in the Construction Industry

Risks in construction projects can be categorized as either subjective or objective risks. Therefore, the analysis and management processes of these risks are mainly based on the type of risk. Objective project risks are described as the risks that are analysed and assessed using actual calculations and observations. These analyses are often related to probabilities and are quantitative in nature including complex calculations, experiences, experimental evidence or previous knowledge (Adams, 2008). However, subjective risks are analysed and assessed depending on people`s beliefs and views. The analysis of this type of risk often uses qualitative methods based on personal experience and available knowledge. Applications and empirical studies of objective risks have been widely demonstrated and studied in the construction industry (Pouliquen, 1970; Bjornsson, 1977; Vidivelli *et al.,* 2017). On the other hand, there is a lack of consideration of subjective risks in the construction industry, especially in conflict zones. Therefore, this research focuses on dealing with subjective risks in construction projects within examination of the increased risk found within conflict zones. Furthermore, the absence of subjective information about particular risks leads to an exploration of people`s perception and their estimations regarding these risks.

Numerous studies have evaluated/assessed risk perception in the construction industry in a range of ways including comparing different attitudes and groups of risk (Findley *et al.,* 2007), asking stakeholders to rate a list of risk factors according to their severity, importance and frequency (Holmes *et al.,* 1999; Enshassi *et al.,* 2009; Mahamid *et al.,* 2012), quantifying the way that people perceive risks using an objective algorithm approach (Jannadi and Almishari, 2003; Hallowell, 2010), requesting stakeholders to participate in ranking qualities of risks such as risk control, risk exposure and risk prevalence (Leiter *et al.,* 2009), and identifying the factors that affect health and safety aspects in construction projects in terms of people`s perceptions and prevention strategies (Gambatese *et al.,* 2008; Schultz and Jorgensen, 2014). Therefore, it is vital to critically understand how risk is perceived in construction projects in order to be able to deal with it appropriately. In order to understand all construction stakeholders' perceptions, an industry-wide discussion about risk should be developed from a range of people in the construction industry (Saunders *et al.,* 2012).

The Nature of the Construction Industry Within Conflict Zones

Conflict can be relatively low-level between communities, or open-surface between states: it can be of short duration or extend over decades. It is considered as a dynamic process that can be changed and developed over time. In other words, the behaviours, attitudes and structures of people are constantly changing and affecting each other in different ways. As the conflict develops, the interests and needs of

people become impossible to fulfil, because those who are involved in the conflict continue to pursue their needs by developing disputing behaviours and hostile attitudes. As a result, the conflict continues to intensify over time and therefore affects different parties (Galtung, 1990). A range of factors directly or indirectly contribute to conflict between parties, including cultural characteristics, difficult living circumstances and personality traits (Staub, 2013). Conflict can happen between friends, communities, nations, groups, neighbourhood, within organizations or even between humans and animals (De Pourcq *et al.,* 2017; Jay *et al.,* 2017; Stephan *et al.,* 2017; Torres *et al.,* 2018). Violence issues such as extreme aggression and infrastructure damage which lead to slow the construction and economic development (Nathalie *et al.,* 2018). This study focuses on the ongoing armed (geopolitical) conflict between Palestine and Israel, because there is a lack in implementing potential construction development, understanding the situation and coping with problems and obstacle. A range of industries and businesses in both Palestine and Israel are seriously affected by this prolonged conflict. These effects include economic loss, investment problems, people`s safety, infrastructure damage, environment and agricultural production losses (Harris, 2010; Arnon and Bamya, 2015). The dominant factors that affect the construction industry in Palestine are restriction in movements, limited construction locations and policy-related problems (Enshassi and Mayer, 2005; Razia *et al.,* 2017). For example, there are unexpected road blockades and closures that limit the movements of people and road from time to time. These closures have directly weakened the potential development of Palestinian plans especially in the construction industry (UNCTAD, 2009). The unavailability of land to implement new construction projects and re-develop existing ones is associated with the devastation that exists in certain areas, which is caused by the ongoing conflict and its unexpected consequences (Arnon and Bamya, 2015). Hence, there are difficulties in finding an appropriate development land and delivering the projects as planned, since both are affected by the closure polices and unsafe places in conflict areas. Due to the nature of conflict, there is a limited opportunity for policymakers to create and apply their development policies. This has led to the formulation of insufficient polices that are unable to meet the development requirements in terms of construction, infrastructure and public services ((UNCTAD, 2017). It is also challenging to transport and deliver construction goods and equipment as well as accessing public services for citizen due to the ongoing long-term conflict.

METHODOLOGY

This study aims to identify how risk is perceived and dealt with in the construction industry in conflict zones in order to provide richer understanding of particular risk situations and respond to it effectively. In order to achieve this aim, the semi-structured interview approach was used in order to gain a deep understanding of the information provided by the participants. The interview approach emphasises that participants have the opportunity to express their views as long as the guidelines of the research are followed. Thus, the reliability of the interview procedures is for specific sample size unrelated to the need and can be selected based on the need for further collection of data (Newton, 2010; Stott, 2014). There are different methods to justify the sample size including precedent where researchers consider identifying studies that adopted the same design, and following recommendations by methodologists (Marshall *et al.,* 2013). For this reason, most stakeholders were recommended by the Palestine Engineers Association and had more than 10 years' experience in the

construction industry and are aware of the construction policies applied. Different stakeholders who involved in the construction industry were invited to participate in this study. Those stakeholders included three contractors, two owners, two consultants, two academics and two policy makers. The process of the semi-structured interviews continued until the stakeholder was either unable to provide more information or repeated the same information. The semi-structured interview process demonstrated that the findings vary among different stakeholders and sometimes unexpected findings may be obtained. All interviews were recorded, transcribed and then translated from Arabic into English. Content analysis is utilised to provide a valid inference from transcripts and compressing several terms and words of text into groups based on particular coding rules (Bryman and Bell, 2007).

FINDINGS AND DISCUSSION

The findings emerging from this research confirm that risk perception in the conflict zones is significantly influenced by various theories including cultural, social and psychometric. Other factors also affect how risk is perceived, such as familiarity, trust, heuristics and controllability. However, the existing literature of risk perception fails to address other aspects that affect stakeholders` perception including the implementation and validations of policies (Sjoberg, 2000). The findings suggest that the implementation processes of polices have significant effects on the way that stakeholders` construct their perceptions. Participants also indicated that it is vital to consider both duration of exposure to risks and imitations - ie situations where stakeholders replicate another's actions or behaviours. Addressing these aspects, along with the existing aspects and variables of risk perception, assists in providing better understanding of how risk is perceived in the construction industry especially in conflict zones, and therefore can facilitate the processes of achieving construction development.

Risk as Imitation

Participants claimed that dealing with risk is sometimes related to the situation and the action that is followed to use other stakeholders` approach. The existing literature of risk and its related aspects especially in the construction industry has limited coverage of imitative behaviour (Holmes *et al.,* 1997; Findley *et al.,* 2007; Mahamid *et al.,* 2012). Therefore, the findings showed that risk imitation has a significant influence on how stakeholders perceive and deal with risks. Participants also argued that in many situations where they are insecure about the risk or reluctant to engage or not with risk events, they usually choose to copy what other stakeholders do in order to deal with particular risk regardless of its potential consequences. In this case, most participants who choose to just imitate what others do, have lesser concern about the likelihood of risk effects and engage more with risks as they simply follow others` action without significant knowledge or thinking. So, the decisions-making process of the followers whether to participate or not in a certain risk is mainly dependent on their ability to do exactly what other stakeholders do in terms of dealing with and responding to risks.

Risk as Polarised

Different aspects of polarization emerged from the findings and provided important issues to be considered in dealing with risk and risk perception. Although the current practices of risk and risk perception evaluated how risk is perceived, and identified the differences of people`s opinion, there is still a lack in providing a holistic insight regarding particular risk events especially in the construction industry within conflict

zones (Slovic, 2000; Arnon and Bamya, 2015). The findings indicated that stakeholders perceive similar risks differently, either with positive or negative consequences based on their experience and knowledge. This leads to providing different identifications and evaluations of certain risks, divides stakeholders` perspectives and leads to difficulties in dealing with risks as these risks carry different estimations. This is very common in conflict zones as the situation is unstable and several factors are likely to change over the duration of a construction project including restrictions in movements and implementation of policies. Therefore, it is vital to consider polarisation-related aspects when evaluating and responding to risks as they assist in providing a better understanding of particular risks from different viewpoints and identifying possible changes that may affect the perception of risk.

The Theme of Risk Engagement and Thought Process

The theme of risk engagement emerged from this study. This describes the process of capability and intention of stakeholder whether to engage or not with particular risk events to attain desired shared outcomes. The current studies of risk perception and risk management focus only on dealing with the factors that influence stakeholders to take risks from an individual's viewpoint, rather than exploring the variables that affect individuals and groups in engaging with risk (Lumpkin and Dess, 2001; Hillson and Webster, 2007). Understanding of risk engagement requires attending to the practices and dynamics of risk in everyday life, in addition to identifying how these are embedded among people (Marston and King, 2006). Although some decisions to engage with certain risks are complicated, others are clear, and it is easy to make an informed decision to engage with them. Hoskisson *et al.,* (2016) argued that managers usually take risks within their organizations in order to improve performance. To explain this, a risk taking attitude seeks to often obtain personal benefits without taking into consideration the potential adverse effect on individuals or workers. However, the aspects of risk engagement concern other stakeholders and groups when experiencing particular risk events. For this reason and due to the ongoing conflict, stakeholders and organizations in the construction industry are required to engage with risk together, rather than as individuals, and consider possible risk consequences on others, in order to achieve their accepted outcomes. The participants also argued that there are different thinking processes that affect shaping their perception and make informed decision. These processes include impacting where stakeholders identify positive or negative effects, alternative process refers to identify available choices or plans, competence concerns of being able to achieve something and informed decision where stakeholders construct their perception and decide to engage or not with particular risk events.

CONCLUSIONS

Construction development is a complex area that requires not just quantitative analyses but the evaluation of qualitative approaches and the acknowledgment of several perspectives, especially when considering aspect-related risk perception. Risk perception plays an important role to achieve the effectiveness of risk management and is considered as a source of significant influence on the process of decision-making. People's different perceptions influence the process of risk management. Therefore, it is vital to understand how stakeholders construct their perception in order to improve the process of risk management. This paper has provided an overview of risk perception and its aspects through presenting the most important approaches including psychometric, social and cultural. This overview has led to the realisation that risk perception and its related aspects focus only on certain areas and have created

limited understanding of risk perception in the construction industry. The concept of risk perception has the capability to support different issues to deal with risk. However, it was seen that the aspects of construction development in conflict zones require multiple perspectives to understand how stakeholders perceive and respond to risk, rather than applying the current practices of risk perception. Several perspectives of construction stakeholders were identified. It is believed that the application of risk perception is able to provide a holistic insight in the conceptual understanding of construction development. This study is useful for allowing both stakeholders and policy makers in construction especially in conflict zones, to better understand the dynamic approach of risk and achieve the desired outcomes of development. Future research is required to validate the knowledge presented in this paper and provide better application to support it within both conflict and non-conflict zones.

REFERENCES

Alkhaddar, R, Wooder, T, Sertyesilisik, B and Tunstall, A (2012) Deep learning approach effectiveness on sustainability improvement in the UK construction industry, *Management of Environmental Quality: An International Journal*, 23(**2**), 126-139.

Akadiri, P O and Fadiya, O O (2013) Empirical analysis of the determinants of environmentally innovation, *Construction innovation: Information, Process,* Management, 13(**4**), 352-373.

Arnon, A and Bamya, S (2015) *Economic and Politics in the Israeli Palestinian Conflict*. Available from http://www.bgu.ac.il/~arnona/aixbook2015_FINALLLLL.pdf [Accessed 17 July 2016].

Bjornsson, H C (1977) Risk analysis of construction cost estimates. *In*: *Transactions of the American Association of Cost Engineers*, 182-189.

Brashers, D E (2001) Communication and uncertainty management, *Journal of Communication*, 5(**1**), 477-497.

Brennan, M C and Cotgrave, A C (2014) Sustainable development a qualitative inquiry into the current state of the UK construction industry, *Structural Survey*, 32(**4**), 315-330.

Brody, S D Zahran, S Vedlitz, A and Grover, H (2008) Examining the relationship between physical vulnerability and public perception of global climate change in the United States, *Environmental and Behaviour*, 40(**1**), 72-95.

Cook, P A and Bellis, M A (2001) Knowing the risk: Relationship between risk behaviour and health knowledge, *Public Health*, 115(**1**), 54 - 61.

De Pourcq, K, Thomas, E, Arts, B, Vranckx, A, Leon-Sicard, T and Van Damme, P (2017) Understanding and resolving conflict between local communities and conservation authorities in Colombia, *World Development,* 83(**2**), 125-135.

Douglas, M and Wildavsky, A (1982) *Risk and Culture: An Essay on Selection of Technological and Environmental Dangers*. Berkeley: California University Press.

Enshassi, A and Mayer, P E (2005) Barriers to the application of sustainable construction concepts in Palestine. *In*: *The 2005 World Sustainable Building Conference*, 27-29 September, Tokyo.

Enshassi, A, Mohamed, S and Abushaban, S (2009) Factors affecting the performance of construction projects in the Gaza strip, *Journal of Civil Engineering and Management*, 15(**3**), 269-280.

Findley, M, Smith, S Gorski, J and O'Neil, M (2007) Safety climate differences among job positions in a nuclear decommissioning and demolition industry: Employees' self-reported safety attitudes and perceptions, *Safety Science*, 45(**2**), 875-889.

Fischhoff, B, Slovic, P, Lichteinstein, S, Read, S and Combs, B (2000) How safe is safe enough? A psychometric study of attitudes toward technological risks and benefits, *Policy Sciences*, 9(**2**), 127-152.

Fragouli, E and Theodoulou, P (2015) The way people and societies perceive the nature and context of risk is different: Due to psychological cultural issues, *East-West Journal of Economics and Business*, 18(**1**), 22-38.

Gambatese, J A, Behm, M and Rajendran, S (2008) Designs role in construction accident causality and prevention: Perspectives from an expert panel, *Safety Science*, 46(**2**), 675-691.

Gaskell, G and Allum, N (2001) *Risk: Two Cultures of Risk*. The London School of Economics and Political Science: London.

Hallowell, M (2010) Safety risk perception in construction companies in the Pacific Northwest of the USA, *Construction Management and Economics*, 28(**3**), 403-413.

Hillson, D A, Grimaldi, S and Rafele, C (2006) Managing project risk using a cross risk breakdown matrix, *Risk Management*, 8(**1**), 61-76.

Hirsch, R A and Baxter, J (2011) Context cultural bias and health risk perception: The everyday nature of pesticide policy references in London, *Risk Analysis*, 31(**5**), 847 - 865.

Holmes, N, Lingard, H, Yesilyurt, Z and De Munk, F (1999) An exploratory study of meanings of risk control for long term and acute effect occupational health and safety risks in small business construction firms, Safety Research, 30(**4**), 251-261.

Jasanoff, S (1998) The political science of risk perception, *Reliability Engineering and System Safety*, 59(**1**), 91-99.

Jannadi O A and Almishari, S (2003) Risk assessment in construction, *Journal of Construction Engineering and Management*, 129(**2**), 492-500.

Klein, W, Lipkus, I, Scholl, S, McQueen, A, Cerully, J and Harris, P (2010) Self-affirmation moderates' effects of unrealistic optimism and pessimism on reactions to tailored risk feedback, *Psychology and Health*, 25(**10**), 1195-1208.

Kos, J M and Clarke, V A (2001) Is optimistic bias influenced by control or delay? *Health and Education Research*, 16(**5**), 533-540.

Krane, H P, Rolstadas, A and Olsson, N O E (2010) Categorizing risks in seven large projects-Which risks do the projects focus on? *Project Management Journal*, 41(**1**), 81-86.

Leiter, M P, Zanaletti W and Argentero P (2009) Occupational risk perception, safety training and injury prevention: testing a model in the Italian printing industry, *Journal of Occupational Health Psychology*, 14(**1**), 1-10.

Mahamid, I, Bruland, A and Dmaidi, N (2011) Delay causes in road construction projects, *Journal of Management in Engineering*, 28(**3**), 300-310.

Marries, C, Longford, I H and O`Riordan, T (1998) A quantitative test of the cultural theory of risk perception: comparison of the psychometric paradigm, *Risk Analysis*, 18, 635-647.

Marshall, B, Cardon, P, Poddar, A and Fontenot, R (2013) Does sample size matter in qualitative research? A review of qualitative interviews in is research, *Journal of Computer Information System*, 54(**1**), 11-22.

Mason, M (2010) Sample size and saturation in PhD studies using qualitative interviews, *Forum: Qualitative Social Research*, 11(**3**).

Nathalie, E, Ghimire, D and Snedker, K A (2018) Fear of violence during armed conflict: social rules and responsibilities as determinants of fear, *Social Science Research*, 71(**1**), 145-159.

Oltedal, S and Rundmo, T (2007) Using cluster analysis to test the cultural theory of risk perception, *Traffic Psychology and Behaviour*, 10(**3**), 254-262.

Onwuegbuzie, A J and Leech, N L (2007) A call for qualitative power analyses, *Quality and Quantity*, 41, 105-121.

Paek, H J, Oh, S H and Hove, T (2016) How fear-arousing news message affect risk perceptions and intentions to talk about risk, *Health Communication*, 31(**9**), 1-12.

Parvathy, P, Shivaprasad H C, Barkur, G and Kamath, G (2015) Risk assessment using AHP in south Indian construction companies: A case study, *International Journal of Engineering Management and Science*, 2(**5**), 283-295.

Peters, E and Slovic, P (1996) The role of affect and worldviews as orienting dispositions in the perception and acceptance of nuclear power, *Journal of Applied Social Psychology*, 26(**16**), 1427-1453.

Pouliquen, L Y (1970) *Risk Analysis in Project Appraisal*. Baltimore: The Johns Hopkins University Press.

Powell, N, Dunwoody, S, Griffin, R and Neuwirth, K (2007) Exploring uncertainty about an environmental health risk, *Public Understanding of Science*, 16(**3**), 323-343.

Ranasinghe, K A M K (1990) *Analytical Method for Quantification of Economic Risks During Feasibility Analysis for Large Engineering Projects*. PhD Thesis, University of British Columbia.

Razia, B, Thurairajah, N and Larkham, P (2017) Understanding delays in construction in conflict zones. *In*: *International Research Conference,* Salford, Manchester, UK.

Renn, O (2004) Perception of risks, *The Geneva Papers on Risk and Insurance*, 29(**1**), 102-114.

Rostami, R and Thomson, C (2017) Sustainable development of the UK construction industry for future. *In*: *2nd International Conference on Civil Engineering, Architecture and Crisis Management*, Tehran, Iran.

Schultz, C S and Jorgensen, K (2014) Achieving sustainable construction heal and safety, *CIB W99 conference*, 2-3 June, Lund University, Sweden.

Sjoberg, L and Moen, B (2004) *Explaining Risk Perception: An Evaluation of the Psychometric Paradigm in Risk Perception Research*. Oslo, Norway, Norwegian University of Science and Technology, Department of Psychology.

Slovic, P (2000) Perception of risk, *In:* P Slovic (Ed.) *Perception of Risk*. London: Earthscan, 220-231.

Vandermoere, F (2008) Hazard perception, risk perception and the need for decontamination by residents exposed to soil pollution: The role of sustainability and the limits of expert knowledge, *Risk Analysis*, 28(**2**), 387-398.

Vidivelli, B, Vidhyasagar, E and Jayasudha, K (2017) Risk analysis in bridge construction projects, *International Journal of Innovative Research in Science, Engineering and* Technology, 6(5), 8271-8284.

Wildavasky, A and Dake, K (1990) Theories of risk perception: who fears what and why? Daedalus, 119, 41-60.

Williamson, J and Weyman, A (2005) Review of the Public Perception of Risk and Stakeholder Engagement. Buxton, UK: Health and Safety Laboratory.

Wogalter, M S, Dejoy, D M, Laughery, K R (1999) Organizing theoretical framework: A consolidated communication-human information processing (CHIP) model. *In*: M S Wogalter, D M Dejoy, K R Laughery (Eds.) *Warnings and Risk Communication*. London: Taylor and Francis, 15-24.

WELL-BEING

MEASURING WHAT COUNTS: WORKPLACE WELL-BEING OF PROJECT PROFESSIONALS

Clara Man Cheung[1], Paul Bowen[2], Keith Cattell[3] and Jocelyn Davis[4]

[1] *School of Mechanical, Aerospace and Civil Engineering, Pariser Building, University of Manchester, Sackville Street, Manchester, M13 9PL, UK*

[2&3] *Department of Construction Economics and Management, University of Cape Town, Private Bag, Rondebosch 7701, Cape Town, South Africa*

[4] *Department of Civil and Environmental Engineering, Project Management Center for Excellence, University of Maryland, 1173 Glenn L Martin Hall, Maryland, US*

Workplace well-being is correlated with improved work performance. However, limited research has focused specifically on the workplace well-being levels of project professionals (PPs) who deliver strategic projects, programmes and portfolios for organisations in various industries including the construction industry. Improving PPs' workplace well-being could improve strategic project outcomes for organisations. Funded by the Association for Project Management (APM), this study measures PPs' workplace well-being using a psychometrically validated scale, the A Shortened Stress Evaluation Tool (ASSET), and benchmarks the results against normative ASSET's General Working Population 2017 database (GWP 2017) to evaluate the relative state of well-being in the project management community. Three of the ASSET core scales were used: '6 Essentials', 'Health well-being', and 'Psychological well-being' scale. Self-reported data were collected from 184 global APM members using an online survey. The results indicated that PPs' health and psychological well-being are at approaching high-risk or high-risk levels in the subscale of 'Strain on psychological health' and 'Sense of purpose'. In addition, all the work stressors that affect PPs' well-being, measured by the '6 Essentials' scale (i.e., 'Resource and communication', 'Control', 'Balanced workload', 'Job security and change', 'Work relationships', and 'Job conditions') are at approaching high-risk or high risk levels. Interventions to improve PPs' wellbeing through addressing the high-risk stressors in personal, team, organisational and professional level are identified.

Keywords: well-being, ASSET, APM, stress, psychological health

INTRODUCTION

In recent decades, nations around the world have recognised that economic measures of success are insufficient to accurately measure how well a county's people are living. Well-being is suggested as a way to amplify the economic measures and provide a more complete picture of a country's success (OECD, 2017). This thinking about having economic and well-being components to measurements of success has moved into organisations across sectors and industries as to improve workplace performance outcomes. For example, the Department for Business, Innovation, and Skills published a comprehensive report that concluded employees' well-being has a

[1] clara.cheung@manchester.ac.uk

Cheung, C M, Bowen, P, Cattell, K and Davis, J (2019) Measuring What Counts: Workplace Well-Being of Project Professionals *In:* Gorse, C and Neilson, C J (Eds) *Proceedings of the 35th Annual ARCOM Conference,* 2-4 September 2019, Leeds, UK, Association of Researchers in Construction Management, 874-883.

significant impact on workplace performance in terms of labour productivity, financial performance, and the quality of output and services (Bryson *et al.,* 2014). A subset of the working population, project professionals (PPs), delivers on strategic projects in many sectors and industries, creating key outcomes for their organisations. To date, however, limited research has focused on assessing the level of workplace well-being for PPs in comparison with the general working population and to identify key factors which enhance or detract from their workplace well-being (Cui *et al.,* 2016). Identifying ways to capitalise on workplace wellbeing strengths of PP's and addressing weaknesses in PPs' workplace well-being is an avenue for improving PPs' workplace well-being and therefore strategic outcomes for their organisations. Against this backdrop, this funded study by the Association for Project Management (APM) aims to deepen our understanding of: 1) the current level of PPs' workplace well-being compared to a valid benchmark of workplace well-being, 2) the factors which support or detract from PPs' workplace well-being; and 3) the preliminary direction of targeted interventions likely to improve PPs' workplace well-being.

LITERATURE REVIEW

Definition and Impact of Workplace Well-Being

Well-being and workplace well-being have gained increasing attention since WWII. Despite this attention, an agreed-upon, singular definition of well-being or workplace well-being has not yet emerged. The Organisation for Economic Operation and Development (OECD, 2017) defined well-being in two broad domains: material living conditions (i.e., income and wealth, jobs and earnings, housing conditions); and quality of life (i.e., health status, work-life balance, life satisfaction). Ryff (1989) defines well-being in of six elements: self-acceptance, positive relations with others, autonomy, environmental mastery, purpose in life, and personal growth. Vakkayil *et al.,* (2017) describes workplace well-being as having both cognitive and affective components, referring to the quality of work experienced by the employee such as an overall feeling of health, job satisfaction, and positive emotions. Common to the various definitions of well-being/workplace well-being, there is general agreement that it includes three elements: psychological, physical, and social well-being According to Grant *et al.,* (2007), psychological well-being (PWB) refers to one's ability to handle the stresses of daily life and maintain a positive attitude and sense of purpose; physical well-being refers to the physical health such as amount of exercise and sleeping habits; social well-being refers to having a positive and supportive social network.

Workplace Well-Being and Its Antecedents

Conceptual models of workplace well-being and its antecedents have been developed in order to support efforts by organisations to improve performance. Notable models of workplace well-being have included: The Job Characteristics Model (Hackman and Oldham, 1980), the Vitamin Model (Warr, 1987), the Demand-Control-Support Model (Johnson and Hall, 1988), and the Job Demands-Resources Model (Schaufeli and Bakker, 2004). These models are not yet supported by psychometrically validated survey tools which could be used to assess workplace well-being and identify strengths and weaknesses contributing to assessed levels thereof. For this study, we chose the A Shortened Stress Evaluation Tool (ASSET) developed by Johnson and Cooper (2003) as it is a psychometrically-validated measurement that assess workplace well-being with an available and substantial normative benchmark (Faragher *et al.,* 2004; Johnson and Cooper, 2003) as well as the antecedents of well-

being (i.e., six workplace stressors), and its performance outcomes (i.e., organisational commitment).

RESEARCH METHODS

Measures

Due to the objective and length restriction of the paper, we chose to present three of the ASSET core scales: '6 Essentials', 'Health well-being', and 'Psychological well-being scale'. By doing so, we can depict the well-being levels of PPs as well as the antecedents that affect their well-being levels, with a view to recommending ways of improving it. First, '6 Essentials' measure the essential six workplace stressors that affect one's health and psychological well-being levels. The six subscales (stressors) of '6 Essentials' are: 'Resources and communications', 'Control', 'Balanced Workload', 'Job Security and Change', 'Work relationships', and 'Job conditions'. Second, the 'Health well-being' scale is measured by two subscales: 'Strain on physical health 'and 'Strain on psychological health'. Third, the 'Psychological well-being' scale is evaluated by two subscales: 'Positive emotion' and 'Sense of purpose'.

ASSET's questions in the '6 Essentials' scale are phrased consistently in the negative, such as "I am troubled that…" and "I do not feel…". The questions of the 'Health well-being' scale ask respondents to identify what physical health issues (such as eating issues and insomnia), and what psychological health symptoms (such as anger and tiredness) they have experienced in the previous three months. For the 'Psychological well-being' scale, it includes questions consider the frequency of experiencing selected positive emotions (such as inspired and alert) and sense of purpose (such as specific job goals and clear job goals).

Questions of all the scales are assessed by respondents using 4-point, 5-point and 6-point scales. All responses are converted to a mean score calculated for each item and converted to sten scores (‘standardised ten score’- on a scale of 1-10: 1-3 = ‘more positive’, 4-6 = ‘typical’7 = ‘cautionary’ and 8-10 = ‘more negative’, or the opposite if reverse coded) to facilitate comparison to the normative General Working Population or GWP. For this study, we benchmarked the PPs' results against the GWP 2017, the norm group, which includes 70,000 responses gathered from 2013 to 2017. The respondents were a range of organisations and industries in the public and private sectors, and in the UK and other countries.

Procedure and Sample Characteristics

The survey population was drawn from the global membership of the Association for Project Management (APM) who completed ASSET online, including demographic questions. Geographic distribution of the respondents comprised: Europe (48%), Asia (45%), and 7% from Africa, Australia and America, collectively. Fifty-five per cent of respondents were female, 60% were either married or living with a partner. The average age of respondents was 38. Industries represented included: construction (20%), education (13%), IT (12%), logistics (10%), and consulting (9%). Job functions included: project or program managers (35%), academic or trainers (16%), with the rest described as project planners, project administrators, and change managers. Forty-eight per cent reported working full-time and working more than 40 hours per week. The useable sample was 184 respondents, representing about 1% of the membership of the APM.

RESULTS

Results are graphically displayed in Figure 1: dark green = more positive than the GWP 2017 (low risk); light green = similar to the GWP 2017; yellow = less positive than the GWP 2017 (approaching high risk); and, red = significantly less positive than the GWP (high risk). The dark bar extending across the 10-point scale graphic represents the sample's results. Overall, the results indicated that PPs' health well-being is at high risk levels in the subscale of Strain on psychological health while the subscale of Strain on physical health is similar to the GWP 2017. For PPs' psychological well-being, it is at approaching high risk levels in the subscale of Sense of purpose while the subscale of Positive emotions is similar to the GWP 2017. As for the subscales of the '6 Essentials', which are the antecedents of one's well-being levels, the results revealed that four work stressors represented by the subscales of 'Resources and communication', 'Balanced workload', 'Work relationships', and 'Job conditions' are at the high risk levels. Meanwhile, the other two subscales of 'Control', and 'Job security and change' are at approaching high risk levels.

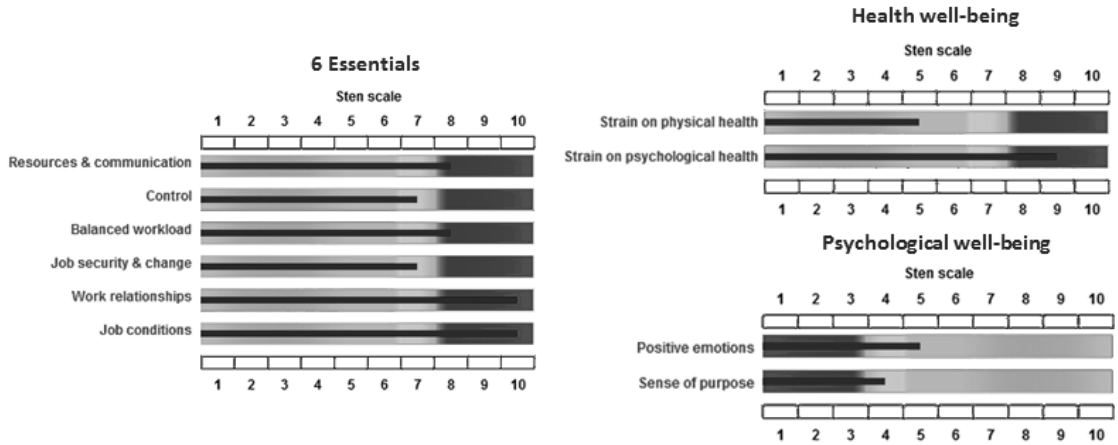


Figure 1. ASSET sten scores of the core scales for PPs

The six workplace stressors measured by the '6 Essentials' were found to be the leading indicators on health and psychological well-being (Johnson and Cooper, 2003). Figure 2 presented the high-risk items of the '6 Essential' subscales (i.e., 'Resources and communication', 'Balanced workload', 'Work relationships', 'Job conditions' and 'Control'), with a view to recommending targeted ways to enhance the PPs' wellbeing in the discussion section. Particularly, PPs are significantly less positive than the norm group in terms of getting sufficient feedback on performance and training, working in unsocial hours, spending excessive travel, experiencing technology overload, dealing with unrealistic deadlines, having negative working relationships with their boss and co-workers, working on dull and repetitive work, dealing with difficult customers, feeling lack of enjoyment and account not taken of staff ideas/suggestion about the job. Against this backdrop, the corresponding interventions were discussed in the next section.

DISCUSSION

"Project-based work has long been characterised as frenetic, fast paced, and dynamic" (Pinto *et al.,* 2014 p.578). PPs typically encounter high expectations and severe pressure to deliver projects on time and within budget, and to reconcile changing expectations of scope due to dynamic factors such as new initiatives from the project sponsor (Smith *et al.,* 2011). Without making a judgement whether PP's have a more

highly stressed environment than other working population, it is clear that respondent PPs are more adversely impacted, at higher risk of lower health and psychological well-being, than are the GWP 2017 (the norm group) benchmark population as shown in Figure 1.

Figure 2. High risk items under the 6 Essential subscales

Specifically, none of the '6 Essentials' scales show that PPs is similar to the norm group. The 'Control' and 'Job security and change' scales measured them as approaching high-risk, whilst the 'Resources and communication', 'Balanced workloads', 'Work relationships', and 'Job conditions' scales were indicated as the high-risk areas that need to be improved in the sake of enhancing PPs' well-being levels. The 'Resources and communications' scale of '6 Essentials' indicated that PPs were at high-risk compared with the norm group, caused by lack of feedback on performance and lack of adequate training to do the job. Perceived lack of feedback on performance made PPs feel stressful because they are unsure whether their work progress is on the right track against the project outcomes and cannot predict what should be done next (Faragher *et al.,* 2004). For PPs who work at non-managerial positions which accounted for 75% of the survey respondents, the feedback is likely coming from project managers. Meanwhile, Meredith and Mantel (2009) has found that project managers tend to engage mostly in task-related activities (i.e., task assignment and specification of the way work is to be conducted), rather than personal-focused motivational activities (i.e., feedback and recognition). This tendency stems from project managers' perception that task-oriented activities directly advance project progress, whereas personal-oriented activities are unfamiliar and time-consuming activities that do not have immediate impact on task or project progress (e.g., Meredith and Mantel (2009); Awikael and Unger-Aviram, 2010). To help project managers break such a perception, organisations not only need to reinforce the importance of providing regular and constructive feedback in terms of improving performance, but also need to establish a structure and process for project managers to give multi-directional feedback. For example, it could be achieved through sharing successes and recognising strong individual performance in weekly team meetings and conducting post event reviews when things go wrong. In addition, perceived lack of training to do the job made PPs feel stressful as they are likely not acquiring skills to meet performance standard (Smith and Sainfort, 1989). Based on the results of the demographic questions in the survey, it showed that 55% of respondents have not acquired any project management qualifications. Under the

circumstance, organisations should help address the issue by supporting PPs to receive proper project management training either in house or externally.

PPs were worse off than the norm group in terms of having 'Balance Workload'. This finding is consistent with previous research by Jugdev *et al.,* (2018) who found that project managers are particularly susceptible to burnout due to having to perform in crisis-ridden environments and the pressure to be available 24x7. Based on the survey results, excessive travel time was highlighted as a particularly serious issue, as were technology overloaded and unrealistic deadlines. Excessive travel time could include the frequency of business travel, daily commuting or frequent project site visit. Although interventions are difficult to be generalized because they must fit the particular requirements of the project in the organisation for which the project is being done, the following are some of the possible interventions for remote project sites or congested commuter systems: 1) provide intermittent overnight stays versus daily commute to PPs; 2) offer flexible start and end times for work to enable PPs to commute at less congested times; and 3) offer compressed work weeks such as four days on and one day off. In addition, PPs reported that they felt overloaded by the technology in their work, but the questionnaire did not allow them to specify what they meant by that. This is a limitation that should be addressed in future studies. One can speculate that it refers to the pace and nature of new software developed for managing project, e.g., cloud-based project management tools. This speculation may be supported by the finding that PPs perceived that they lacked adequate training to do the job. Furthermore, unrealistic deadlines have been consistently shown to be common stressors in project management (Soderlund, 2005). Although it is unlikely that organisations will voluntarily apply less time pressure on PPs, they can enable PPs to set more realistic deadlines by providing them with training on learning project planning techniques and mastering the related software, such as Microsoft Project, in order to perform the job more accurately and efficiently.

PPs felt that they had insufficient control over their work because their ideas or suggestions about the job were not being taken seriously. On the contrary, increasing control can help people to encounter negative effects of other work stressors such as work-life imbalance and heavy workloads (Noor, 2002). It is possible that existing work practices that result in lack of feedback, insufficient job training, and low decision latitude cannot be easily changed at the organisational level. However, professional project management organisations such as APM and Project Management Institute (PMI) and government agencies such as Health and Safety Executive (HSE) could become powerful agents of transformation through developing best practice guidelines for member firms or related industries.

The 'Work relationship' scale of the 6 Essentials revealed that PPs were at high-risk compared with the norm group. Almost all the subscales under the Work relationships scale were at high risk. PPs felt they did not have enough support from their bosses and colleagues. This, taken together with a high level of concern over poor relationships with bosses and colleagues, leads to the inference that this could be a complex issue. In general, good relationships at work not only can make people feel energised at work, but it also enables high levels of work engagement and job satisfaction even if they work under stressful working conditions (Bakker and Demerouti, 2008). Conversely, poor relationships lead to strain and affect health and performance negatively (Faragher *et al.,* 2004). Particularly, PPs reported that their bosses have aggressive management styles, fail to provide clear goals, and tend to focus exclusively on fault finding. To address these issues, organisations could

consider training managers on the keys to team formation (Tuckman and Jensen, 1977) so that they know how to support project teams from forming to performing stage. This is especially important on projects where team members may lack prior working relationships. It is also important for organisations to review and revise project practices, if necessary, to support fair and timely staff performance actions on retrain, reassign and replace. In addition, collegial relationships should be fostered at work to support better performance outcomes (Nagami *et al.,* 2010). This is especially true on project teams where new relationships may need to be formed to support effective team performance (Tuckman and Jensen, 1977). Some possible interventions to improve the relationships include: provide training for all project team members on how to use appreciation to build relationships and intrinsic motivation (Dysvik and Kuvaas, 2008), how to create positive emotional work environments (Vacharkulksemsuk and Fredrickson,2013), and how to practice active and constructive listening skills.

As for PPs' work condition, job enjoyment or satisfaction within this subscale represents the highest risk, followed by dealing with difficult customers/clients, and dull/repetitive work. Personal characteristics such as marital state, gender, age, and education levels contribute to an individual's level of job satisfaction (Gazioglu and Tansel, 2006). Nevertheless, interventions to improve PPS' job satisfaction include: 1) clearly define and communicate the meaning or purpose of the project to PPs; 2) support PPs to align their personal purpose with the project's purpose ; and 3) implement job crafting (Tims *et al.,* 2016), which allows team members to redefine how to get the work done and to consider innovative ways to share work to enhance overall team and individual satisfaction; and 4) implement strengths assessments and strengths-based management to support effective job crafting, alignment with purpose and job satisfaction. In fact, Seligman *et al.,* (2005) found that when people identify and use one of their signature strengths in a new and different way every day for a time interval of up to 6 months, their happiness levels were significantly improved while depression symptoms were alleviated. In practice, PPs tend to work hard to manage weaknesses in order to prevent project failure. Strength-based training provides them with a new lens to focus on what is right, what is working, and what is strong. Consequently, as PPs are more engaged and energised at work, the high-risk items under job condition, such as dull and repetitive work, and enjoyment of work, could also be improved. Finally, to enhance PPs' abilities to successfully deal with difficult customers/clients, organisations may need to provide training on teaching influence and negotiation skills.

CONCLUSIONS

The aim of this study was to explore the workplace well-being of project professionals using the ASSET scale, with a specific focus on global members of the Association of Project Management. Several key findings emerge from the study. The results revealed that PPs' health and psychological well-being are at approaching high-risk or high-risk levels in the subscale of 'Strain on psychological health' and 'Sense of purpose'. Particularly worrisome are the scores for all the work stressors that affect PPs' well-being (i.e., 'Resource and communication', 'Control', 'Balanced workload', 'Job security and change', 'Work relationships', and 'Job conditions') are at approaching high-risk or high-risk levels. This is a concern, but it also provides an opportunity for intervention.

This study provides pointers regarding the areas of concern in relation to the workplace well-being of project professionals. Employer organisations, the industry, and the government need to take cognisance of these findings, actively engage with project professionals, and implement intervention strategies to address the high-risk problem areas.

This study is not without its limitations. The survey was cross-sectional in nature, hence test-retest reliability could not be investigated. In addition, the self-reporting nature of the survey, coupled with the voluntary nature of participation, might reflect individuals with very strong views either way about workplace well-being. We acknowledge the potential bias inherent in this as a limitation of the study.

ACKNOWLEDGEMENTS

The authors acknowledge psychological well-being specialists Robertson Cooper Ltd. who gave permission for the use of the ASSET, and assisted in the collection and analysis of data.

REFERENCES

Bakker, A B and Demerouti, E (2008) Towards a model of work engagement, *Career Development International*, 13(**3**), 209-223.

Bowen, P, Edwards, P, Lingard, H and Cattell, K (2013) Predictive modelling of workplace stress among construction professionals, *Journal of Construction Engineering and Management*, 140(**3**), 04013055.

Bryson, A, Forth, J and Stokes, L (2014) *Does Worker Wellbeing Affect Workplace Performance?* HM Government, Department for Business Innovation and Skills, 14-15.

Cattell, K, Bowen, P, Cooper, C and Edwards, P (2018) The relative well-being of construction professionals, *In*: Joint CIB W099 and TG59 International Safety, Health, and People in Construction Conference: Coping with the Complexity of Safety, Health, and Wellbeing in Construction, 1st - 3rd August, Salvador, Brazil, 292-301.

Cui, Q, Davis, J.S and Huang, H (2016) How happy are project managers in their jobs, *In:* Chan, P W and Neilson, C J (Eds.), *Proceedings 32nd Annual ARCOM Conference*, 5-7 September 2016, Manchester UK Association of Researchers in Construction Management, 649-656.

Dizaho, E K, Salleh, R and Abdullah, A (2017) Achieving work life balance through flexible work schedules and arrangements, *Global Business and Management Research*, 9(**1**).

Dysvik, A and Kuvaas, B (2008) The relationship between perceived training opportunities, work motivation and employee outcomes, International Journal of Training and Development, 12(**3**), 138-157.

Faragher, E B, Cass, M and Cooper, C L (2005) The relationship between job satisfaction and health: A meta-analysis, *Occupational and Environmental Medicine*, 62(**2**), 105-112.

Grant, A M, Christianson, M K and Price, R H (2007) Happiness, health, or relationships? Managerial practices and employee well-being trade-offs, *Academy of Management Perspectives*, 21(**3**), 51-63.

Gazioglu, S and Tansel, A (2006) Job satisfaction in Britain: individual and job-related factors, *Applied Economics*, 38(**10**), 1163-1171.

Hackman, J R and Oldham, G R (1980) *Work Redesign*. Massachusetts: Addison-Wesley.

Johnson, S and Cooper, C (2003) The construct validity of the ASSET stress measure, *Stress and Health*, 19(**3**), 181-185.

Johnson, J V and Hall, E M (1988) Job strain, work place social support and cardiovascular disease: A cross-sectional study of a random sample of the Swedish working population, *American Journal of Public Health*, 78(**10**), 1336-1342.

Johnson, S J, O'Connor, E M, Jacobs, S, Hassell, K and Ashcroft, D M (2014) The relationships among work stress, strain and self-reported errors in UK community pharmacy, *Research in Social and Administrative Pharmacy*, 10(**6**), 885-895.

Jugdev, K, Mathur, G and Cook, C (2018) Linking workplace burnout theories to the project management discipline, *International Journal of Managing Projects in Business*, 11(**1**), 198-221.

Nagami, M, Tsutsumi, A, Tsuchiya, M and Morimoto, K (2010) Job control and co-worker support improve employee job performance, *Industrial Health*, 48(**6**), 845-851.

Noor, N M (2002) Work-family conflict, locus of control and women's well-being: Tests of alternative pathways, *The Journal of Social Psychology*, 142(**5**), 645-662.

OECD (2017) *Measuring Well-Being and Progress*. Paris: OECD Publishing.

Pinto, J K, Dawood, S and Pinto, M B (2014) Project management and burnout: Implications of the Demand-Control-Support model on project-based work, *International Journal of Project Management,* 32(**4**), 578-589.

Robertson, I and Cooper, C (2011) *Well-Being: Productivity and Happiness at Work*. Basingstoke: Palgrave Macmillan.

Ryff, C D (1989) Beyond Ponce de Leon and life satisfaction: New directions in quest of successful ageing, *International Journal of Behavioural Development*, 12(**1**), 35-55.

Schaufeli, W B and Bakker, A B (2004) Job demands, job resources and their relationship with burnout and engagement: A multi-sample study, *Journal of Organizational Behaviour*, 25(**3**), 293-315.

Seligman, M E, Steen, T A, Park, N and Peterson, C (2005) Positive psychology progress: empirical validation of interventions, *American Psychologist*, 60(**5**), 410.

Smith, D C, Bruyns, M and Evans, S (2011) A project manager's optimism and stress management and IT project success, I*nternational Journal of Managing Projects in Business*, 4(**1**), 10-27.

Steptoe, A, Deaton, A and Stone, A A (2015) Subjective wellbeing, health and ageing, *The Lancet*, 385(**9968**), 640-648.

Tims, M, Derks, D and Bakker, A B (2016) Job crafting and its relationships with person-job fit and meaningfulness: A three-wave study, *Journal of Vocational Behaviour*, 92, 44-53.

Tuckman, B W and Jensen, M A C (1977) Stages of small-group development revisited, *Group and Organization Studies*, 2(**4**), 419-427.

Wang, X and Armstrong, A (2004) An empirical study of PM professionals' commitment to their profession and employing organizations, *International Journal of Project Management,* 22(**5**), 377-386.

Warr, P (1987) *Work, Unemployment and Mental Health*. Clarendon Press, Oxford.

Vakkayil, J, Della Torre, E and Giangreco, A (2017) It's not how it looks! Exploring managerial perspectives on employee well-being, *European Management Journal*, 35(**4**), 548-562.

Vacharkulksemsuk, T and Fredrickson, B L (2013) Looking back and glimpsing forward: The broaden-and-build theory of positive emotions as applied to organizations, *In*: A Bakker, A (Ed.) *Advances in Positive Organizational Psychology,* Bingley: Emerald Group Publishing Limited, 45-60.

INDEX OF AUTHORS

INDEX OF KEYWORDS