ARCOM

Association of Researchers in Construction Management

ARCOM DOCTORAL RESEARCH WORKSHOP

Sustainability in the Built Environment

Environmental Building Group
School of Architecture, Design and Environment
University of Plymouth, UK

Rolle Building 201 & 202, University of Plymouth

16 November 2009

Workshop Chairmen:	Prof. Mike Riley Dr. Wei Pan
Workshop Coordinators:	Dr. Wei Pan Dr. Pieter de Wilde

University of Plymouth

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10:30 – 11:00	The dimensions of sustainable development: What do we know already? *Dr. Paul Chan, University of Manchester*
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INTRODUCTION

There are increasing global concerns related to climate change and sustainability in the built environment. Buildings contribute some of the largest environmental impacts. For instance, nearly half of total UK carbon dioxide emissions come from energy use in buildings[1], more than half of all public water supply in England and Wales is for household use[2], 32% of all landfill waste comes from construction and demolition of buildings, with 13% products delivered to construction sites being sent directly to landfill without being utilised[3]. The UK Government published its strategy for sustainable construction in 2008, and has set a number of challenging targets for improving sustainability, e.g. reducing total UK carbon dioxide emissions by at least 60% on 1990 levels by 2050, with zero carbon new-build homes by 2016 and all new buildings by 2019 for England and Wales, and 50% reduction of construction, demolition and excavation waste by 2012 compared to 2008[4]. All these targets, coupled with the current economic recession, have challenged the industry to explore effective ways to achieving sustainability. Additionally, all present Government funding has sustainability targets attached. There is thus both a need and an opportunity for research in the disciplines relating to sustainability in the built environment and studies that for instance lead to a better understanding of the concept of sustainability and the measurement and management of sustainable construction etc.

This ARCOM workshop was focused on sustainability in the built environment with the purpose to help the researchers develop the area and highlight some of the research approaches being taken. Prof. David Coslett, Pro Vice-Chancellor of the University of Plymouth and Executive Dean of the Faculty of Arts opened the workshop and welcomed everybody to the City and the University. This was followed by a brief introduction of ARCOM and ARCOM workshops by Dr Paul Chan from the University of Manchester. Dr Chan highlighted the contribution of ARCOM to the research community, which celebrated its 25th anniversary at the 25th ARCOM Conference at Nottingham in September 2009. After that, Prof. Mike Riley welcomed all to the Workshop and started the scientific debate with a short speech on addressing sustainability using a systems approach. Then five papers were presented, each presentation lasting around twenty minutes followed by ten minutes discussion. A 'hot' debate was opened after all the presentations, and the Workshop finished with an informal networking session. Through this process, the presenters benefited from the feedback on their work and all the participants were provided with an insight into current sustainability research.

The Workshop Proceedings include the five papers presented and another two that were submitted but could not be delivered at the Workshop for varied reasons. In these papers, Chan argues that knowledge is presently incomplete in terms of what we know about sustainability, and outlines a salient review of the four capital dimensions of sustainable development, i.e. man-made, human, social and natural capital. Davis critiques that, despite many previous research efforts, supply chain management sophistication in construction is

[1] *Building a Greener Future: policy statement*, Department of Communities and Local Government, London, 2007.
[2] *Strategy for Sustainable Construction*, Department for Business, Enterprise & Regulatory Reform, London, 2008.
[3] *Waste Strategy for England 2007*, Department of Environment, Food and Rural Affairs, Norwich, 2007.
[4] Same as no.2.

still at a very low level in comparison to many other industries. Davis proposes a Soft Systems Methodology (SSM) as a means for supply chain management practitioners to develop lean supply in construction holistically, taking into account the unique culture and fragmentation feature of construction. Carfrae presents his research in establishing the boundary conditions that define a safe level of moisture content in straw bale walls. Carfrae develops an improved probe for measuring the moisture content of straw bale walls demonstrating that it is possible to get accurate measurements of the moisture content of a straw bale wall using a relatively simple home-made timber-block probe. Murray argues that while there is a natural tendency for educators to focus on the scientific and technological aspects of sustainability and sustainable construction, this approach will not necessarily maximise the positive contributions professionals have to offer. Murray suggests that this is because it does not address the intrinsic motivations people need if they are to embrace the positive changes sustainability requires. He introduces a new initiative developed at the University of Plymouth for engaging learners directly with the sustainability agenda. Leblanc presents sustainable refurbishment of the existing building stock as the most sustainable solution compared to demolition and new build. Leblanc argues that knowledge management systems are to be presented as effective tools to increase the sustainability level of refurbishment projects within the context of social housing in the UK. Barghchi *et al.* report on research in sports facilities development in Malaysia. Despite an increase in the amount of public money being spent on sports facilities construction, the existing facilities are under-utilized and not economic oriented. Barghchi *et al.* suggest that to guide the planning system to focus on the concept of sustainable development is a new approach to planning and design. They recommend further research in the physical, economic and social impacts of sports facilities development on urban development in Malaysia. Loh *et al.* emphasise that strategic selection of sustainable materials and building design prior to the building construction is crucial to increasing building life cycle energy performance. They argue that stakeholders involved in the early design process often have conflicting priorities for both building design and construction materials which makes decision making a complex task. Loh *et al.* develop an Environmental Assessment Trade-off Tool (EATT) with Analytical Hierarchy Process (AHP) incorporated and highlight how this system can be used to inform the design of low carbon energy efficient buildings.

All of these papers, together, present a useful insight into the current research in addressing sustainability in the built environment. It is interesting to see the diversity of research covered in this fairly small-scaled one-day workshop. Possibly, such diversity is a reflection on the wide-ranging attempts to define sustainability and measure sustainable development. But the themes, around technology, ‘soft’ institutions, and behaviours, of sustainability research embedded in the papers of these proceedings will certainly contribute to the relevant future debate in the wide community.

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THE DIMENSIONS OF SUSTAINABLE DEVELOPMENT: WHAT DO WE KNOW ALREADY?

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Sustainability has become an important catch phrase in political, business and academic discourse. From environmental concerns regarding global warming and climate change to the sustenance of economic prosperity, policy-makers at governmental and corporate levels are increasingly putting more credence to the sustainability agenda. In this paper, however, it is contended that there is a lot of hype surrounding policies and practices of sustainability. To a certain extent, this recent buzzword is old wine filled in an old bottle for what should be commonsensical good practice. It is argued that knowledge is presently incomplete in terms of what we know about sustainability. As such, it is crucial that the sustainability movement steers towards more evidence-based policy and practice. Furthermore, it is suggested that practitioners should remain reflective on both the successes and failures of endeavours towards a more sustainable future especially in terms of how sustainable policies and practices interact with human agency. In this paper, a salient review of the four capital dimensions of sustainable development will be outlined.

Keywords: disconnections between policy and practice, incomplete knowledge,

DEFINITIONS AND PERSPECTIVES

The Pearce (2003) report introduced the concept of sustainability by drawing on the UK Government's (1999: 8) definition of "ensuring a better quality of life for everyone, now and for generations to come". Pearce (2003) proffered a framework for understanding the application of sustainability in the British construction industry, including the four perspectives of man-made, human, social and natural capital.

Man-made capital: problems with an output-driven model

The construction industry is often credited as being the sector that underpins business, industry and general way of life in any country. In the UK, recent statistics from the former Department of Trade and Industry (DTI) indicate that the industry employs around 1.2 million workers producing an output of just over £107 billion at current prices in 2005 (DTI, 2006). Though sizeable, Pearce (2003) noted that official statistics tend to diminish the true picture of the industry because data derived from a narrow definition only account for the contribution of contractors, and not the broader inclusion of the quarrying of raw materials, production and sale of building materials and products, professional services, self-build and the informal economy.

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From a man-made capital perspective, nevertheless, the principal focus appears to be on raising productivity. For instance, Pearce (2003) argued that the industry's contribution to man-made capital, particularly in terms of infrastructure provision, lags behind our major competitors in Europe on per capita basis. Elsewhere, there is also general recognition of the current housing shortfall to meet the demographic changes (see Barker, 2004). These comparisons point to the long-standing productivity problem in construction (Ive et al., 2004; Blake et al., 2004).

Yet, there is also contrasting evidence to suggest otherwise. Barrett (2005), for instance, tracked the gross value added figures for the UK construction, manufacturing and service industries since 1975 and found that the construction industry actually outperforms manufacturing. Even the UK productivity gap with that of our European counterparts in official statistics appears to be closing (Ive et al., 2004; Blake et al., 2004). These estimates suggest that the productivity gap between British and European construction industries (esp. France and Germany) is closing rapidly, and what needs to be bridged is the gap between British and US construction. Indeed, Blake et al. (2004) suggested that the UK construction productivity gap can be bridged by seeking to learn from 'best practice' of US construction. However, such a recommendation can be too simplistic and problematic. Broadberry and O'Mahony (2004), for example, stressed that there are limitations to wholesale copying of practices from other countries due to barriers such as geographic differences; contextualising practices is necessary for any improvement strategy to be adopted.

Of course, there is also the problem with the measurement of productivity is not without problems. There is indeed a lack of consensus as to how productivity should be measured (Blake et al., 2004; Ive et al., 2004). Critics have observed that construction productivity measurements have not hitherto painted an accurate picture of the complexity of the production process. Crawford and Vogl (2006), for instance, suggested that the dominant emphasis on macro-level measures of productivity fails to account for the entirety of the construction process at the micro-level. Moreover, as Recently, Flanagan et al. (2005) suggested that it is perhaps time to move away from measuring outputs to the measurement of value derived from such issues as quality, innovation and organisational learning as they urged for a paradigmatic shift towards competitiveness instead.

Human capital: the rhetoric versus reality of investing in people

The concept of human capital is not new. Ever since Adam Smith examined the pin manufacturing process in the 18th century, the importance of human capital in the form of skills and dexterity of the workforce has been acknowledged. However, as Grugulis (2003) points out, "the longstanding consensus that skills are 'good things' […] and the evidence that they can advantage every participant in the employment relationship have not been matched by a widespread adoption of high skills routes to competitiveness. Despite the existence of exemplary practice, extensive exhortations and official interventions, most jobs in Britain demand few skills. (p. 7)".

If human capital is espoused to bring benefits of productive capacity for the firm and the worker, why is there a mismatch between the rhetoric and reality of training and education investment? Construction researchers have offered a number of explanations for this phenomenon. The central argument tends to revolve around the nature of the industry. The construction industry is often exposed to the vulnerabilities of economic cycles of boom and bust. Given such uncertainties, firms are less likely to engage in skills training and development, which requires a longer-term view. Furthermore, the industry epitomises the pinnacle of flexible organisation and its deeply entrenched reliance on self-employment (Winch, 1998) and contingent labour (Forde and MacKenzie, 2007) reduces the industry's propensity to train. Together with the difficulty in attracting new entrants into the industry as a result of its beleaguering public image, it is inevitable that the industry consistently reports a low average training investment of around one-person-day per year.

Furthermore, as in the case of defining productivity, there is an ever-expanding explanation of what skills really mean and who should be responsible for 'paying' for skills. Becker's (1964) suggested that there is a distinction between firm-specific skills and skills that are completely general. It follows logically therefore that the investment of firm-specific skills should lie within the remit of firms and that the state through its education system should provide for the general skills since an increase in worker productivity should in theory benefit the economy as a whole. However, most skills learned on the job may be somewhere between the extremes of firm-specific and general, and there is a growing desire of employers to pursue more generic rather than firm-specific skills (Grugulis et al., 2004). Therefore, the distinction between specific and general skills is less clear-cut and it is more plausible to consider a continuum of types of training based on the extent to which training is transferable to other firms.

Given the ever-expanding understanding of what skills mean, this implies that that the economic perspective promoted by human capital economists like Becker (1964) is limited in attaining the ideal state of more skills leading on to greater productive capacity for both the firm and the worker. Instead, employers are inclined to abdicate from the responsibility of investing in skills development (Dainty et al., 2005) for fear that other employers would poach the workers once they have completed the training. Evidence is, in fact, mounting that show the shifting employer preference for general skills and lends further support to the de-skilling of firm-specific skills.

Grugulis et al. (2004) provided a more cynical outlook: the growing desire of employers to focus on generic skills offers on the one hand a false sense of upskilling among the workers and on the other virtually no benefit of wage premium. Becker's (1964) belief that investment in human capital would reap benefits of greater productive capacity and wage growth would stand to be tested. In fact, recent evidence in the UK construction industry showed little correlation between skills levels and wage rates (Clarke and Herrmann, 2004). Arguably, the economic perspective of human capital emphasises human resources as an economic factor of production and potentially plays down the human benefits that can be accrued through development. The view on human capital seems to be divided into two camps: economists who are largely concerned with economic performance and productivity and sociologists who defend the power of labour in the social construction of skills. A compromise is perhaps needed to move forward in engendering real action from the debates. Sympathetic commentators have suggested that construction companies have to juggle between the short-term need for profitability and the long-term employee interests of skills development. Raidén and Dainty (2006) used the phrase 'chaordic organisation' to describe how construction companies deal constantly with both the chaotic business environment and the orderly, strategic planning of skills. Raidén and Dainty (2006) recommended for more research to examine the characteristics of construction organisations as chaordic organisations.

Natural capital: consensus gained or paradise lost

The concept of natural capital in relation to the sustainability agenda was popularised in the 1980s by the late Professor David Pearce (Pearce et al., 1989; Turner, 2006). According to Turner (2006), Pearce viewed natural capital "[…] as a fruitful way of integrating ecological sensitivities into mainstream economics (p. 198)". It is fair to say that few would dispute climate change to be an issue of the day. Particularly in the West where governments struggle to encourage the electorate to vote, today's politically-apathetic youth are likely to be interested in such single issues as climate change and the environment.

Researchers from the field of ecological economics have distinguished between two forms of sustainability: weak sustainability and strong sustainability. The weak sustainability perspective views natural capital and man-made capital as substitutes such that the depletion of any one form of capital is acceptable insofar as reinvestment in other forms of capital takes place in order to maintain or increase the total stock of natural and man-made capital. The measurement of weak sustainability tends to follow a cost-benefit approach and is invariably commensurable with monetary valuation. The strong sustainability perspective, on the other hand, considers natural and man-made capital to be complementary and that all natural and other forms of capital should not only be kept independently intact over time, there is also a need to maintain essential, non-replaceable and non-substitutable environmental resources (see Devkota, 2005; Turner, 2006). Therefore, the preservation of the natural environment and its resources is central under strong sustainability.

However, Neumayer (1999) provided two plausible reasons as to why the pursuit of sustainability, especially strong sustainability, can be a struggle: "If the current generation still thinks that additional precautionary action is warranted, it should do so […] Natural and economic science is able to guide in making this decision transparent and rational. It will not be able to give the answer in the society's stead, however. This is for two reasons: First, both the natural and economic science of global warming is unable to provide unambiguous answers about how much emission abatement is warranted. Uncertainty and ignorance are too widespread […] Second, the answers are dependent on the underlying ethical decisions concerning how much to take the future welfare into account and whether one thinks that what future generations care about is only total capital or specific sub-categories like natural capital. Ultimately, it is on us to decide whether we think consumption growth can compensate future generations for damage to natural capital and human health or not (p. 41)." To put simply, the first reason relates to the measurement problem and the incompleteness of scientific knowledge; whilst the second reason points to a sense of morality and ethical behaviour.

In construction, both the measurement problem and ethical issue are equally relevant. Take the delivery of zero-carbon housing, one of the most recent aspirations of the UK government in the pursuit of greater energy efficiency and the Kyoto protocol targets

(Lowe, 2007; Banfill and Peacock, 2007) for example. The residential sector in the UK accounts for about 30% of the UK's total carbon emissions (Boardman et al., 2005; Banfill and Peacock, 2007). Interestingly, Boardman et al. (2005) reported, "Contrary to experience in most countries, UK carbon emissions have fallen in recent years, being around a fifth lower in 2003 than in 1970 (p. 11)." Therefore, whilst reduction in carbon emissions is vital, curtailing of energy consumption is more important in the formulation of UK energy policy. Afterall, as Banfill and Peacock (2007) argued, one of the major impetus driving public policy and regulatory change in the UK is the security of energy sources to maintain projected energy-intensive lifestyles: "The proposals [...] assume that existing lifestyle trends will continue, with the growth of home entertainment, large-screen televisions, more brightly illuminated homes and more consumer electronics, and that these must be catered for (p. 429)." Thus, this lends further support to the argument that consumption growth is what drives public policy and that the attainment of strong sustainability remains to be an elusive aspiration (Wackernagel et al., 2004; Herring, 2006; Spash, 2007).

Despite the boldness of the policy proposals (which are laudable), the reality appears disconnected. Schiller (2007) suggested that debates surrounding the contribution of construction towards sustainable development had hitherto been emphatically framed around the aspects of new buildings. Schiller (2007) maintained that attention needs to be given to the provision of urban infrastructure, which he argued is as resource-intensive as new-built projects, if policy-making were to derive a long-term view. What Schiller highlighted is the incompleteness of knowledge surrounding the construction industry's contribution to sustainable development.

There is the further issue of refurbishing and adapting the existing building stock. Boardman and colleagues (2005) concluded, as part of the 40% house project, that there needs to be an increase in the demolition rate to 80,000 dwellings per annum across the UK, a rate last achieved in 1975. There are indeed concerns as to whether current industry's capacity can cope with such scale of demolition (Lowe, 2007). Similarly, Banfill and Peacock (2007), when critiquing the policy on zero-carbon housing, suggested that both institutional mechanisms and the industry's supply chain were currently inadequate to meet the proposed targets by 2016. Lowe (2007) was optimistically cautious: "The conversion of the UK house-building industry and supply chain to one capable of delivering 160,000 to 200,000 passive houses per year by the middle of the next decade will be an enormous task. If the UK is ultimately successful, it will have achieved more in the next seven years than Germany, where the standard has been developed, has achieved in the last 17 (p. 347)." To succeed, there needs to be political urgency and a strong will for implementation to milestones in a set timescale (Boardman et al., 2007). However, recent experience of the changes to Part L of the building regulations that govern energy efficiency of buildings (Lowe, 2007) and the vagaries of performance-based building regulations (Gann, 1998) suggests that success of political will remains to be seen.

And if the challenge of political will is not enough, there is the battle to change the hearts and minds of consumers. As mentioned previously, consumption growth has been the underlying assumption driving public policy. Arguably, this somewhat pessimistic approach is due to the fact that the knowledge on current consumer behaviour regarding to the use of buildings from an energy perspective remains patchy (Chappells and Shove, 2004). Still, there is a growth on work in this area. Wood and Newborough (2003) investigated how the use of domestic appliances can lead to potential savings in energy. Pett and Guertler (2004) examined how people actually use energy efficient systems installed in their homes. Still, more research needs to be done to examine consumer behaviour from a holistic and dynamic approach; and until such evidence is available, researchers can only rehearse the need for adjustments in taxation/incentives (Banfill and Peacock, 2007) and the education of consumers (Boardman et al., 2007) at an abstract level.

Social capital: building trust and sustainable communities

In a recent BBC documentary entitled How we built Britain (2007), presenter David Dimbleby reveals how the built environment, through its architecture, can inspire people in their social and economic activities. In one episode, he recounts British philanthropy as he visits Saltaire, a Victorian industrial village north of Bradford in West Yorkshire, UK. Saltaire was designated as a world heritage site by UNESCO in 2001 (see http://www.saltaire.yorks.com). However, its humble beginnings stemmed from the vision of its founder, Sir Titus Salt, Mayor of Bradford in the 1850s and a businessman in the clothing industry. Titus Salt was aware of the acute poverty that struck the Victorian working classes, and so, he embarked on a project to build, amongst other things, decent houses, a school, hospital and leisure facilities in an attempt to elevate living standards for his workers. The efforts were remarkable at a time when the struggles of the working classes were largely ignored by fervent capitalists; and arguably, increasing worker welfare probably led to higher production in Salt's mills. It is perhaps unlikely that Titus Salt labelled his achievements in Saltaire as the creation of a sustainable community or indeed a contribution to social capital – but this is precisely what he did!

Notwithstanding Salt's intentions (whether altruistic or not), the development of places like Saltaire deserves greater examination, especially given current political interest in the sustainable communities' agenda. Salt's primary focus appeared to hinge on three things: a roof over one's head, a place for work and leisure, and opportunities for maintaining (and developing) one's well-being. A century and a half later, these basic principles still hold true for the development of sustainable communities. But, far from being straightforward, the definition of sustainable communities is fraught with problems and is continually debated by policy-makers, practitioners, academics and communities themselves.

Thus, the reality of 'doing' sustainable communities presents more challenges when compared to 'thinking' in policy terms. Bridger and Luloff (2001) argued, "In our opinion, the central theme behind many of the recent attempts to recapture a sense of community is the recognition that such a task requires alternative constructions of place – symbolic, economic, and physical constructions which reduce the alienation of people from one another and from the environment (p. 460)." It is precisely this reduction in alienation that the extant literature discusses the need to involve, and seek the buy-in, from the communities concerned when developing such symbolic, economic and physical constructions of what a sustainable community looks like. However, as Bridger and Luloff (2001) point out, "[…] community studies document numerous barriers to broad involvement and the high level of activeness envisioned by proponents of sustainable community development (p. 458)". They added, "[…] leadership and participation are largely limited to local elites whose interest in development often has much more to do with private gain than community well-being (p. 463)".

Indeed, there are limits to community participation and consensus building among end users in shaping sustainable communities. Evidence of good practice remains patchy, and small-scale examples on delivering schemes with user input tend to be confined to certain segments of public-sector building (see e.g. Zeisel, 2003). In the UK, developmental work on design quality indicators (Whyte and Gann, 2003) is intended to provide a common set of measurement criteria for stakeholders to engage in a dialogue about design of the built environment. It is perhaps appropriate that Whyte and Gann (2003) entitled their paper Design quality indicators: work in progress for several authors subscribe to the view that it is extremely difficult to evaluate design in an objective sense (see Rouse, 2004; Macmillan, 2006). Exploratory work by Abdul Samad and Macmillan (2005), for instance, tried to get stakeholders to self-assess such intangibles in the school environment as calmness and security and safety when making decisions across schemes. In their conclusions, they discussed the degree of uncertainty with regards placing a value on such intangible measures. Furthermore, there is the question of who gets to vote on these measures from the community, the risk of participant selection as indicated by Bridger and Luloff (2001). Macmillan (2006) asserted that more needs to be done by both researchers and professionals in terms of creating evidence-based design that integrates the valuation of intangibles.

Similar to our argument about the other capitals previously, the limitation of understanding sustainability from a social capital perspective is limited by economic dominance. Coleman (1988) asserted, "[…] the concept of social capital constitutes both an aid in accounting for different outcomes at the level of individual actors and an aid toward making the micro-to-macro transitions without elaborating the social structural details through which this occurs (S101)". This assumes, once again, that it is possible to measure objectively the different outcomes in a disaggregated fashion. Such an economic approach leads to the problem of reductionism, which consequently results only in partial successes in policy formulation and implementation. In our discussion on sustainable communities, we have shown that it is just as important to elaborate the social structural details, which is given scant attention by theorists like Coleman (1988) who advocates rational action theory where "people are viewed as purposive agents who make rational, deliberate choices to maximize their utility (Bridger and Luloff, 2002: 467)". A deeper sociological exposition of the relationship between the changing social structures and agents involved is required to fully understand the power of social capital in our quest for sustainable development. In so doing, it is essential to examine how decisions on sustainable communities are made in such a collective manner that transcends the utility of individual agents that departs away from mere abstract notions of trust and altruism.

CONCLUDING REMARKS

An attempt was made to sketch out the developments in the literature surrounding the key concepts of man-made, human, natural and social capitals in the pursuit of sustainable development based on a framework initiated by Pearce (2003). From this salient review, a number of observations can be made. First, there is a wealth of knowledge established on measuring the various capitals. So, whether it is about cross-country comparisons of productivity, or skills levels depicted by human capital investment, or carbon emissions and energy consumption, or the levels of trust in social relationships, there is a huge preoccupation on measurement. However, measurement is only as good as the criteria chosen, and our discussion above reveals that there is often a lack of consensus regarding both the criteria and the final measurements themselves. Knowledge about the various capitals and their contribution to sustainable development remains, at best, incomplete.

The partial knowledge is due to the dominance of the economic approach in defining all four capitals. This brings about two limitations. First, economic measurements tend to rely largely on the ability to place a monetary value on some chosen criteria. Throughout, it has been repeatedly shown that this monetary evaluation alone can be arbitrary and lead to a level of reductionism that is often unhelpful for both policy formulation and implementation. Second, the economic perspective generally views humans as rational beings, whose sole purpose of survival is to maximise economic utility. This translates only to partial understanding of such complex problems as skills shortages and climate change. Furthermore, such abstraction could lead to people at the grassroots feeling disenfranchised, argubaly in the case of social capital and the formation of sustainable communities. Third, there is also the limitation of the economic perspective in dealing with the age-old problem of the free-rider. As we have seen, sustainable development often involves some level of public good, e.g. in the development of skills, the shift towards energy conservation, and the notion of the community. The economic solution may seem straightforward – a combination of free market mechanism and governmental intervention of market failures. However, the reality lies in the complexity associated with market failures and the issue of human behaviour in response to governmental intervention.

The extant literature across all four capitals suggests a need to consider, at the very heart, the importance of human agency – an aspect which is unfortunately downplayed in policy-making and much of the economics literature. Yet, the success of any sustainable development endeavour depends on appropriate interactions between socio-political/economic structures and human agency, and increasingly at the local community level. Perhaps less is more in relation to the ever-expanding realm of measurement is needed if we were to move forward in the quest for sustainable development. What is needed is policy formulation and implementation that accounts for the complexities of human agency and a deeper understanding of how these eventually shape institutional structures (and vice versa). Both the economic and sociological perspectives to the four capitals have been presented. However, these two perspectives often talk at each other (often to their backs). Integration of these perspectives is necessary to understand the complex interrelationships between the four capitals presented here.

ACKNOWLEDGEMENTS

This paper is an abridged version of part of one chapter on sustainable development in a forthcoming book entitled Constructing futures to be published by Wiley-Blackwell. Please do cite without consent of the author.

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USING SOFT SYSTEMS METHODOLOGY TO DEVELOP LEAN SUPPLY IN CONSTRUCTION PROJECTS

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For over a decade the UK government has been active in urging the construction industry to improve how it manages its supply chains. Yet despite these efforts research has shown that supply chain management (SCM) sophistication in construction is still at a very low level in comparison to many other industries. Often citing the manufacturing industry, much of the government's focus has been on encouraging organisations to make their supply chains leaner. However, the construction industry has a unique working culture and high levels of fragmentation that differentiates it from manufacturing. This makes lean supply for most constructed products a very different proposition to that of most factory manufactured products. Soft Systems Methodology (SSM) is identified as a means for developing lean supply in construction. It is argued that the SSM approach can enable SCM practitioners in construction to view the process of developing lean supply holistically, allowing them to take into account the culture and fragmentation that they might face.

Keywords: Lean Supply; Soft Systems Methodology; Culture; Fragmentation

Introduction

The UK construction industry accounts for approximately 8% GDP (Shelbourn *et al*, 2006), with an annual output of £79.4bn generated by 182,664 mainly private contractors employing 1,169,000 people (DTI, 2006). It is a highly fragmented industry with a significant concentration of small and medium sized enterprises (SMEs). The top 30 private contractors account for just 17% of output (Fernie *et al*. 2003). In comparison BAE Systems accounts for approximately 60% of the output in the UK aerospace industry (Green *et al*, 2005).

The industry is also characterized by its inefficiency and antiquatedness (Egan, 1998), and as a result there have been a number of initiatives over the past 20 years, most with government endorsement, to help address these issues. Constructing Excellence (the government back body born out of the Egan report) estimate that the products and services in the typical construction supply chain account for 80% of the cost of a project (www.constructingexcellence .org), so many of these initiatives partly or wholly focus on improving SCM, and in particular making supply chains "leaner" by removing systemic waste.

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A highly influential endorsement of "lean thinking" is "Rethinking Construction" (Egan, 1998). Citing the success of Toyota's (lean) Production System (TPS) in Japan, and in particular its ability to replicate this success in its overseas operations, Egan proposed that lean and lean supply could be adopted into UK construction practices as a means of "sustaining performance improvement". He assured that despite conventional opinion, construction has many similarities to industrial manufacturing, for example, a high occurrence of "repeat products" and "repeat process(es)". Figure 1 highlights the benefits of lean in construction according to Odgaard (2005):

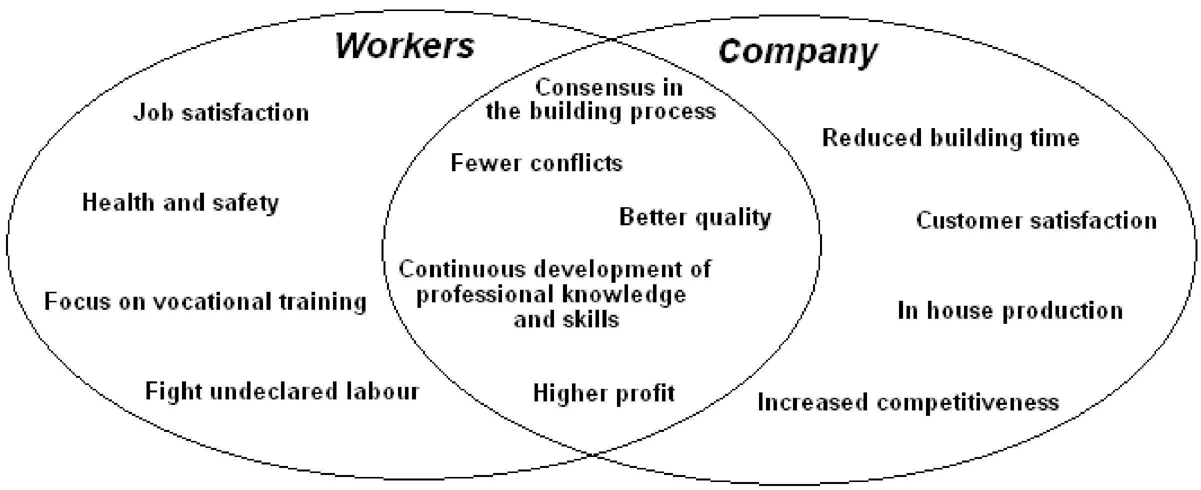


Figure 1: The benefits of lean construction (Odgaard, 2005)

To what degree lean supply has diffused into the construction industry as a result of what Naim and Barlow (2003) call this "government exhortation" is hard to fully quantify and is the subject of ongoing research, all be it relatively limited. In terms of company size, according to Mossman (2009) much of the take up of lean has been by privately owned medium sized firms. This phenomenon is suspected to be a function of their "form of ownership" (rather than their abundance) as directors of private SMEs are not subject to the "short-termism" of shareholder reporting and the stock exchange, and therefore can take a "longer view" with respect to a sustainable lean strategy. One of the exceptions to the size criterion (although they are still privately owned) is Laing O'Rourke. Their logistic centre and off-site manufacturing system used to facilitate near Just-In-Time (JIT) material deliveries during the construction of Heathrow Terminal 5 (Dawson et al, 2008) being a high profile example of lean supply in construction.

In terms of numbers of take up, a national survey of UK house builders by Barker and Naim (2008) showed that approximately 37% had not heard of Lean Supply principles, 36% had heard of them but had never used them, 21% had used them sometimes, and 6% had used them extensively. In comparison, by 2001, approximately 96% of the UK aerospace industry was at least aware of the benefits of Lean Supply (Harrison *et* al. 2002).

Culture

To help put their work into context Barker and Naim (2008) reported some responses as to why practitioners believed that SCM sophistication and ultimately lean diffusion was so low in comparison to many other industries. These responses indentified ignorance, cultural barriers and a general lack of appropriate resources across the sector, for example, *"Company very set in its ways. p.s. most people here think 'Latham' was a cricketer" – Good luck*. Such sentiments are not new (for example, "The Simon Report" in1944), nor are they uncommon across the industry. Green *et al*. (2005) found the issue of cultural barriers to *"transcend all other issues"* amongst SCM practitioners in construction. The enduring view was that the "dinosauristic" culture was hindering the implementation of SCM, and whilst it was seen to be changing for the better, the rate of change was still too slow for construction, as a whole, to achieve the level of sophistication experienced in other industries in the near future.

Another distinguishing aspect of construction culture in the UK are reports of the use of fear as a motivator, and that it's the "modus operandi" of many construction companies (Mossman, 2009). This is a serious consideration when contemplating lean supply development because the whole philosophy is firmly rooted in empowerment, trust and participation (Bicheno, 2004), reflecting Deming's (1986) insistence that meaningful systemic improvement cannot happen in a fear driven environment.

There are also the practical aspects of "going lean" to consider within the cultural context. It typically takes three to five years to embed a continuous improvement culture in manufacturing, and doing the same in construction is likely to take considerably longer (Mossman, 2009), certainly longer than the duration of most construction projects.

Fragmentation

Unlike modern manufacturing, the UK construction industry is characterized by its multi level fragmentation (Baiden et al. 2006). Supply chains normally exist only for the duration of a project (Vrijhoef and Koskela, 1999), and as a result there is little incentive for actors within the chain to work and learn together. This is compounded by the fact that these actors will often see the others as adversaries as a result of "traditional" procurement processes, contract arrangements (Cullen et al. 2005), the conflicting nature of demand and supply (Cox and Ireland, 2002) and contractors only focusing on the 1st tier (Briscoe and Dainty, 2005). The "partnering" movement stemming from Latham (1994) was designed to address this situation, and there have been some successes, but these for the most part have only involved the "major players" (Mossman, 2009).

This fragmentation also manifests itself physically. The distance between the production site and suppliers changes with every new project. Not only does this pose challenges to communication, but more importantly challenges to transportation – a core focus of lean supply (Jones and Womack, 2003).

An innovative way to develop lean supply on construction projects

The characteristics of its culture and the fragmented nature of the UK construction industry make developing lean supply for most construction projects a much more complex task than doing the same in traditional manufacturing, and the repeated "exhortations" that urge construction to learn and copy from other industries give little attention to this (Green *et al*, 2005).

Slow cultural change is not exclusive to construction. But the fact that most construction projects are of relatively short duration means that culture will not change dramatically during that timeframe and efforts to exhort cultural change would usually amount to a waste in itself (although enforced change naturally modifies culture a little (Checkland and Scholes, 1990)). Previous examples of lean supply in construction have shown that bringing actors within the supply chain around to lean thinking and participating in the journey is not unrealistic (Ballard, 2008). However it can be argued that for "lean supply in construction" to achieve the desired level of success, the solutions that are implemented must be as culturally feasible as possible. This coupled with the multi level fragmentation of the industry and supply chain means that an SCM approach that can view the entire problem systematically and holistically, and that can deconstruct complexivity is needed. One approach that affords practitioners this capability is soft Systems Methodology (SSM).

Soft Systems Methodology (SSM)

SSM, as advocated by Checkland and Scholes (1990) stems from research into solving "real world problems" carried out in the late 1960's at the University of Lancaster in the UK. It was originally seen as a business process modelling/re-engineering tool, but now it is also being seen as a powerful learning and meaning development tool (Williams and Imam, 2007). SSM is firmly embodied in the philosophy of *Systems Thinking* - the idea that the world with all its idiosyncracies, problems and quirks can be better understood by thinking of it holistically. Holistic meaning that no dimension of culture can be understood in isolation, cultures are integrated wholes (Checkland, 1891). Winter and Checkland (2003) describe systems thinking as *"thinking holistically or 'seeing the big picture'—a mode of thinking which is complementary to the more reductionist thinking of natural science in which the emphasis is on 'breaking things down' and looking at things in detail"*. Systems thinking was philosophised by the likes of Aristotle and Plato, so it's not necessarily new or novel. Yet it only relatively recently has begun to develop a more widely accepted philosophical base.

Systems thinking is a broad field, a continuum with the "hard" at one end and "soft" at the other, with "hard" being the much more accepted and practiced (in many ways similar the quantitative and qualitative research "approaches"). Literature most often refers to "hard", and essentially traditional systems thinking as being associated with testing hypothesis using quantitative data (Jacobs, 2004). SSM offers an alternative, and encourages users to focus more on the fuzzy ill-defined areas of problems like the human interaction and cultural perspectives, ultimately viewing humans as "components" (Maqsood et al, 2006).

Mayon-White's (1993) map (figure 2) helps to indicate where SSM stands historically and theoretically in relation to its systems thinking "peers".

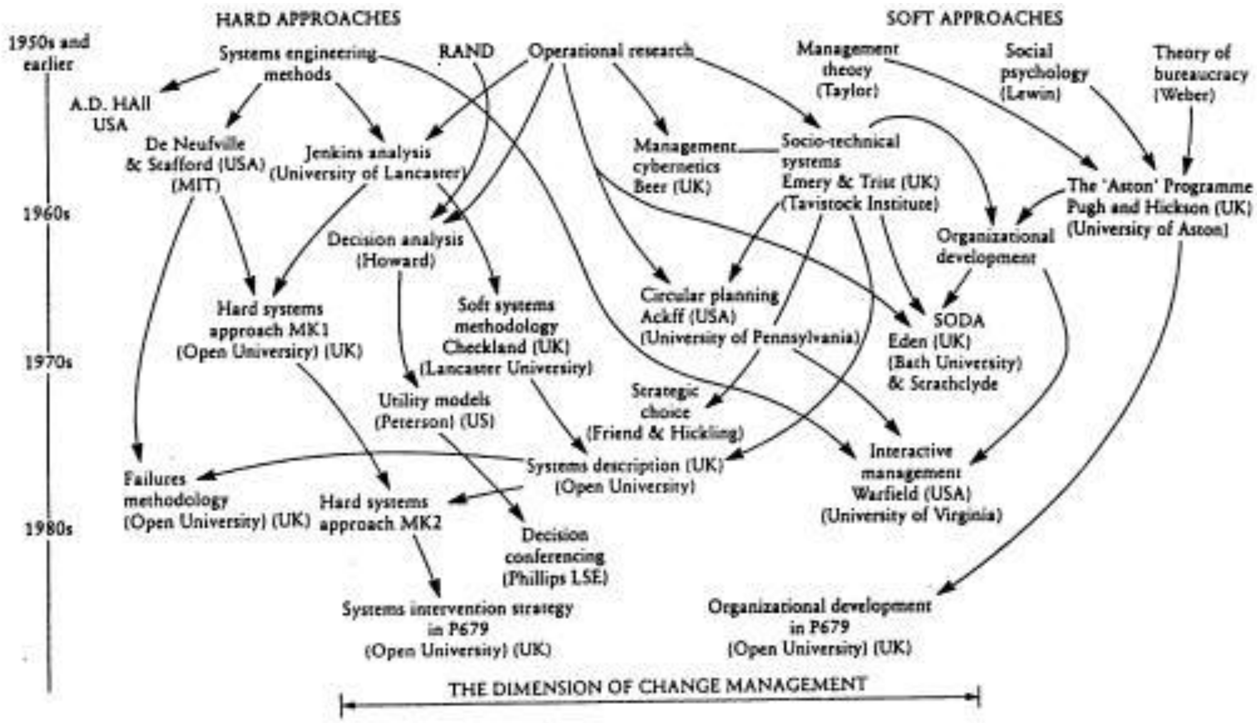


Figure 2: Historical and theoretical map of systems thinking (Mayon-White,1993)

So to summarise:

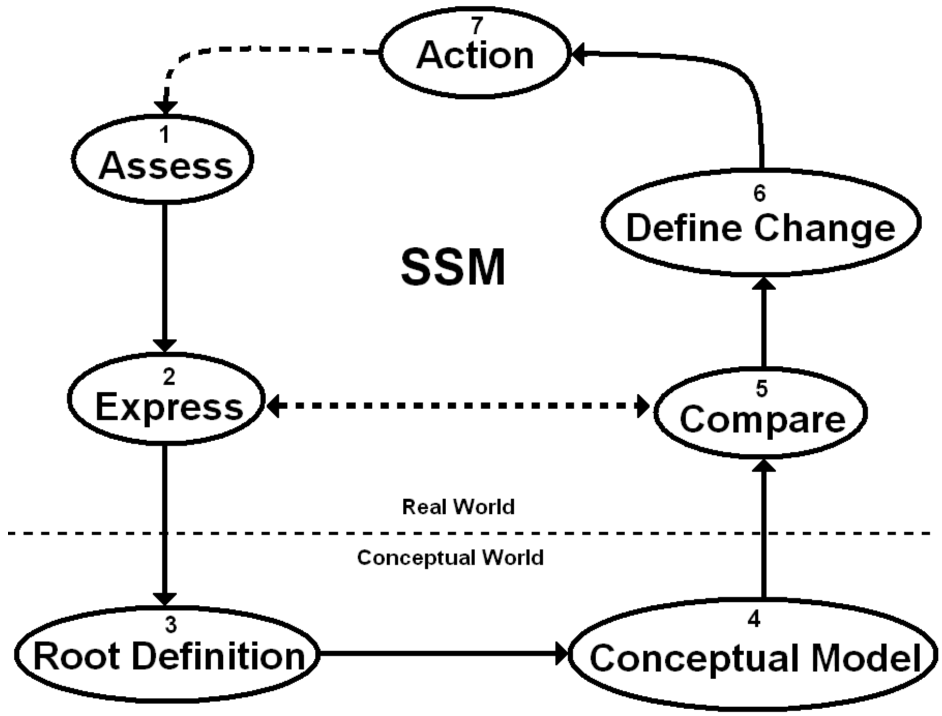
Soft relates to the concept being primarily related to people and how they think and interact with one other and their environment.

Systems relates to the need to think systemically about these people, their relationships, procedures and resources.

Methodology relates to it being an organised way of thinking. It is a process of analysing where we currently stand, where we think we should stand, and developing the appropriate actions to get us there.

The Stages of SSM

SSM is a "cyclic learning system" (Bergvall-Kareborn, 2002) traditionally containing seven stages. Some address the "real" world, some the "conceptual world. The stages are: assess the problematic situation, express the situation pictorially or graphically, determine the root definitions, create a conceptual model, compare the conceptual model with the real world situation, define the changes required to address the problem and take appropriate action (Figure 3).



Stage 1: Assess the Problematic Situation

The first stage of the SSM process is to acknowledge and define the "problem situation", and assess why it is of particular interest. This could involve a preliminary gathering of relevant literature and other material, a meeting to discuss peoples' current viewpoints, or whatever is deemed appropriate to give one an overall awareness and initial explanation of the problem. This is often an arbitrary starting point, and the initial assessment may shift as the problem situation is better understood (Williams, 2005).

Stage 2: Express the Situation Pictorially or Graphically

The second stage of the SSM process is to express the problem situation. This is achieved by representing the problem in the form of a "Rich Picture". Modern business management tends to be overwhelmingly dominated by number and text and drawing pictures in order to better understand problems is often seen as primitive and wasteful - but it has been proven that pictures are an excellent way for humans to organize and express complex problems (Checkland, 1990). Through the Rich Picture we attempt to encapsulate reality through pictorial representation of all the core elements that constitute a given situation: for example, connections, relationships, cause-and-effect, influences etc.

There are many examples where rich pictures have proved to be a valuable tool, and not just when used for a full SSM programme. For example, Jacobs (2004) reported that rich pictures *"provided a springboard for in-depth analysis of the problem situation"* when endeavouring to bring about performance improvements and organisational change within the English National Health Service (NHS) using SSM. Whereas Naim and Barlow (2003) used rich pictures independently of SSM to present their work on reengineering housing supply chains to become both lean and agile because they helped *"to understand problems and potential solutions without becoming obscured by minutiae"*. Not only does the work of Naim and Barlow show the potential of rich pictures as a tool for communication of complex problems, but it also gives an example of the applicability of rich pictures when developing lean supply in construction, particularly when considering the issues of culture and fragmentation. Their rich picture of a "traditional" house building supply chain is shown in Figure 4.

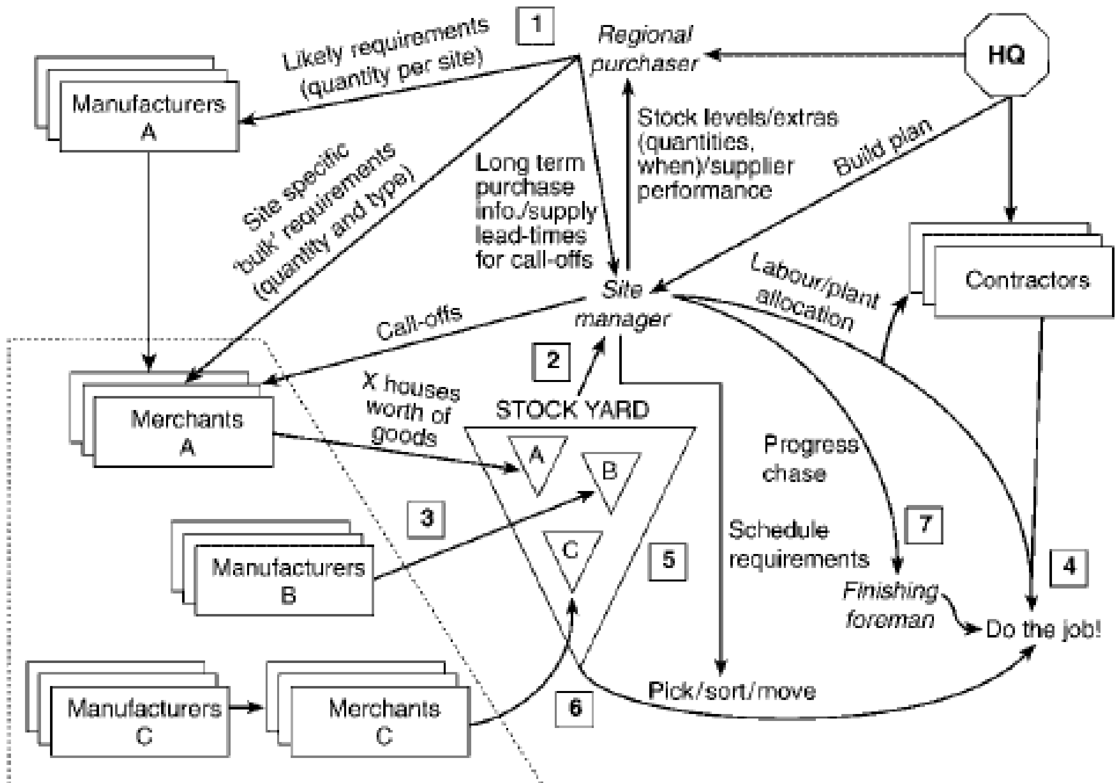


Figure 4: Rich picture of traditional house building supply chain (Naim and Barlow, 2005)

Stage 3: Root Definitions

The third stage of the SSM process moves out of the real world and into the conceptual world of systems. This is the stage from where improvement "grows" which is why Checkland (1981) calls it the "Root Definition" stage. The aim of this stage is to develop a concise, logical textual (root) definition that can *"express the core essence of the perception to be modelled"* (Checkland and Scholes, 1990). It should follow the basic formula of *"a system to do X, by means of Y, in order to Z"*.

The development of the root definition should be further guided by a technique called CATWOE Analysis. CATWOE Analysis is a powerful technique that allows the identification of important components of a system, which in turn affords a better understanding of a given situation. The CATWOE mnemonic is as follows:

Customers: Those who benefit or suffer from the output of the named system.

Actors: Those who perform the Transformation tasks within the named system.

Transformation: The conversion of Inputs to Outputs for the named system.

Worldview: What makes T meaningful. Why we are *really* doing it? The bigger picture. The wider impacts.

Owners: Those with the power to stop T

Environment: The limitations and constraints that could have an impact on the solution and its ultimate success.

CATWOE is firmly embedded in cultural and stakeholder analysis. Therefore it has the potential to play an effective role in the understanding construction management issues, for example, improving Knowledge Management (Maqsood et al, 2007) and Risk Management (Smith, 1999).

Stage 4: The Conceptual Model

The fourth stage of the SSM process is to develop a *conceptual model*. The conceptual model shows the sequence of activities and their logical dependencies that complete the transformation process described in the root definition and the CATWOE analysis.

Stage 5: Comparison of Conceptual and Real World

The fifth stage of the SSM process is to evaluate how the conceptual model compares to the perceived reality: what *might* happen compared to what *does* happen i.e. comparing the conceptual model to the rich picture. This process unearths activities that are poorly done (or not done at all), and ultimately provide the platform for an appropriate management strategy to be identified. The comparison is carried out by analysing each activity in the respective model by way of asking the following key questions: Is the activity actually done? How is it done? Who does it? How do we assess its performance? How is this process performing at the moment? The analysis is normally recorded in tabular form, or what is commonly known by SSM practitioners as the *matrix approach* (Checkland and Scholes, 1990).

Stage 6: Defining Change

The sixth stage of the SSM process is to determine what changes are to be made in order to improve or address the problems identified in stage five. This is the stage when intense discussion and debate is encouraged. Obviously there can be many solutions for any given problem, so there needs to be a way of determining the most appropriate one. Born out of its “humanistic” focus, SSM dictates that for the highest chance of success these changes must be *Systemically Desirable* and *Culturally Feasible*.

Systemic Desirability means that the changes made to improve the existing system must reflect the insight gained through the SSM process i.e. not the changes that *we* in isolation think *we* want, but rather what the system wants.

Cultural Feasibility takes into account that culture has a significant impact on change (particularly with Lean implementations (Bicheno, 2004)) and every problem situation will have an associated culture. SSM defines culture in problem situations being primarily made up of social and political systems. Social systems are constantly changing interactions of three elements: roles, norms and values. Roles are positions of social importance that are institutionally or behaviourally defined, the expected behaviour is the norm, and the performance of that role is judged against established values (Checkland and Scholes, 1990).

Furthermore a role is characterised by expected behaviour otherwise known as norms. Political systems are where differing interests are accommodated through expressions of power, or hierarchy. This power may be expressed in a number of ways, for example, personal charisma or membership to a particular committee (Kotadis and Robinson, 2008) or union (Wilson, 1984). Therefore, for change to be successful, that change itself must be as socially and politically acceptable as possible i.e. “This means something to us, it’s realistic, and we can work with it”.

Pragmatically, Patching (1990) suggests that *Technical Feasibility* and *Financial Feasibility* should also be considerations at this stage (although he concedes that these considerations are normal practice when developing such proposals). It should also be noted that Jones and Womack (2002) advocate that ideally, lean supply should be implemented for little of no cost.

Take Action

The final stage of the respective cycle is determining what actions are required to implement the solutions identified in stage six. These solutions once implemented, will alter the problem situation. So in principle a new cycle of SSM can begin. Consequently the problem may be continually reviewed, and therefore the system continuously improved. Also, the lessons learned and the knowledge gained can be applied to other situations, for example, designing value into supply chains.

Conclusions and Proposed Implementation

It has been argued that the success of lean supply in construction is heavily influenced by the unique culture and fragmented nature of the industry. This paper has put forward the case for using SSM to develop lean supply in construction due to it having the scope to identify and analyse these influences. The next phase in this research is to test the hypothesis that SSM is an innovative and effective way of developing lean supply in construction by applying in it to a physical project during the construction phase. It is proposed that a workbook will be supplied to supply chain practitioners working on a medium sized MoD construction project in southern England where it will be used to help develop lean supply. The focus of the work will be on the interface between the construction site and first tier. The validity of using SSM will be analysed using case study method incorporating semi-structured questionnaires.

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LONG TERM EVALUATION OF THE PERFORMANCE OF A STRAW BALE HOUSE BUILT IN A TEMPERATE MARITIME CLIMATE

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This paper presents findings from doctoral research project at the University of Plymouth whose main focus is to establish the boundary conditions that define a 'safe' level of moisture content in straw bale walls, and to develop an improved probe for measuring the moisture content of straw bale walls demonstrating that it is possible to get accurate measurements of the moisture content of a straw bale wall using a relatively simple 'home made' timber-block probe. The research also covers the findings from on-going research project investigating the durability of straw bale walls in the UK. This research is focused on the Totnes Eco House, a timber frame and straw bale house built in the South West of the United Kingdom in 2005. The influence of the Gulf Stream in this region of the UK creates a mild damp climate that is potentially the very damaging to straw bales. The paper discusses the long term monitoring of the straw bale walls of the house. The results show that when covered with an appropriately hygroscopic finish, straw bale walls can withstand elevated moisture contents, as long as the environmental conditions allow the straw to dry back to below the level considered harmful. Where conditions mitigate against the drying of the straw, the use of a simple timber rainscreen is shown to greatly improve the moisture performance. This work is considered useful to architects, designers, contractors, insurers and self-builders involved in the design and construction of straw bale buildings in temperate climates.

Keywords: Post Occupancy Evaluation, Moisture, Monitoring, Non-food crops, Straw bale.

Introduction

There is increasing concern and awareness of environmental issues such as climate change, depletion of fossil fuels, pollution of natural resources, and damage to eco-systems. There are many contributory factors to these changes, but as far as this paper is concerned, two statistics stand out. The first is the fact that in 2008, 27.5% of final energy consumption in the United Kingdom (UK) came from domestic dwellings(MacLeay, Harris and Michaels 2009) and that 10% of the total energy used in this country is embodied in construction materials(Harris and Borer 2005). Current legislation from Government and initiatives from within the construction industry are focused on lowering the energy used during the lifetime of new buildings, but some of these proposals (such as mechanical heat recovery) will also significantly increase their embodied energy. This has resulted in an understanding that it is essential for architects and designers of low energy houses to take

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account the fabric embodied energy and the origin of their construction materials(Atkinson 2008). One group of materials of increasing prominence with low embodied energy is that of renewable materials or “Non-Food Crops”, such as straw bale, hemp-shiv, flax, reed, jute and sisal(Yates 2006). However, there are some concerns of the long term effects of moisture on these materials, particularly in a temperate maritime climate, such as the UK(Lawrence, Heath and Walker 2009).

In 2005, the University of Plymouth started monitoring a timber and straw bale house that had been constructed in Totnes, South Devon, UK. Measuring the straw bale walls for moisture content began immediately upon completion. The house has been monitored for almost four years since November 2005, and has provided an invaluable source of data on the long-term moisture performance of straw bale construction(Carfrae, deWilde, Goodhew, Walker and Littlewood 2008). A variety of methods have been used to measure the moisture in the walls of the Totnes Eco House including various prototype timber-block sensors, a Protimeter ‘Balemaster’(GE_Sensing 2006), temperature and relative humidity probes and gravimetric analysis. In June 2007 a fault in the execution of an external drip detail was discovered, which had allowed the ingress of moisture into a section of the external wall. This provided an excellent research opportunity to assess the moisture performance of the wall design and materials. Once the defect was eliminated, a detailed analysis was undertaken of the pattern of drying of the straw bale wall over the course of a year, providing a unique contribution to this field of research. In addition, this paper looks at the role of a timber rain-screen(Carfrae, Goodhew, deWilde, Littlewood and Walker 2009) in helping to prevent the problem discussed in this paper happening for other straw bale dwellings in the UK.

Description of the Totnes Eco House

The Totnes Eco House was designed to have a minimal impact on the environment both in the construction phase and during its life span. One of the decisions that underpinned this design philosophy was to avoid the specification of construction materials with high-embodied energy content, such as concrete. This decision also influenced the sourcing of the chosen construction materials, attempting to obtain them as close as possible to the site in order to cut down on transport energy and associated carbon dioxide emissions, and in addition to potentially support the local economy. It was therefore decided to use timber for the building’s structural frame, straw bales for the external walls, loose sheep’s wool for additional insulation and lime based renders for exterior and internal wall coverings. The finishes used on this form of wall should be airtight but vapour permeable, which will allow the water vapour that is created inside the dwelling to migrate to the outside without becoming trapped inside the wall. This is a form of construction known as a ‘breathing’ wall. This has benefits for the indoor air quality, but more importantly, it is generally recognised that a vapour permeable finish is important in protecting organic materials such as timber and straw, in that it mitigates against any build up of moisture and the potential for damage that could ensue(Summers 2006).

Three coats of fat lime render with an average thickness of 25mm protect both sides of the straw exterior walls. This render is made from three parts of sharp sand to one part lime putty, which is the result of slaking quicklime in water. This material is more hygroscopic, and has greater vapour permeance than lime based renders that contain a percentage of cement(Straube 2000). When detailing a wall build up of this kind, it is important that the degree of permeability of the different finishes on each side of the wall is balanced. In a temperate climate, the warm interior air will almost always contain more moisture, with a higher vapour pressure than the cooler air outside. The moisture from the inside will travel through the wall to the lower pressure on the exterior face of a building. So to avoid the water vapour building up to the point where it can condense into water droplets (known as interstitial condensation), it is important that the inside face of the wall should be less permeable than the outer, always encouraging the flow of vapour to the outside.

Development of the Timber Disc Moisture Probe

The initial monitoring of the house was undertaken with a timber-block sensor. An inexpensive and easy to build probe for measuring the moisture content of the straw in a straw bale wall was first developed in Canada, and the design was published in 1996 by the Canada Mortgage and Housing Corporation (CMHC)(Fugler 1996). Further details appeared In the Spring 1998 issue of The Last Straw(Fugler 1998). This article discuses two prototype probes designed by Dr Vandrish, one of which used a relative humidity meter that was taken apart and the sensor embedded in the wall, the other one used a small piece of balsa wood encased in a perforated tube. Habib John Gonzalez (owner of ‘Sustainable Works’) published a simplified version of the second design using a timber disc(Gonzalez 1998), and it is this design that has been used more recently by Goodhew et al(Goodhew, Griffiths and Woolley 2004), and is the model that was first installed in the Totnes house(Carfrae *et al.* 2008). Professor Goodhew had made revisions to the 1998 design including some small differences in the way that the probe was constructed, and a more significant modification in that the variety of timber used was changed from the white pine used by Gonzalez to oak, following comparative testing at the University of Plymouth(Bryant 2004).

This moisture probe is designed to be easy to manufacture, and at a reasonable cost. They consist of a small piece of timber in a perforated tube that is inserted in the wall, with a pair of wires attached to the timber going to the outside (figure 1).

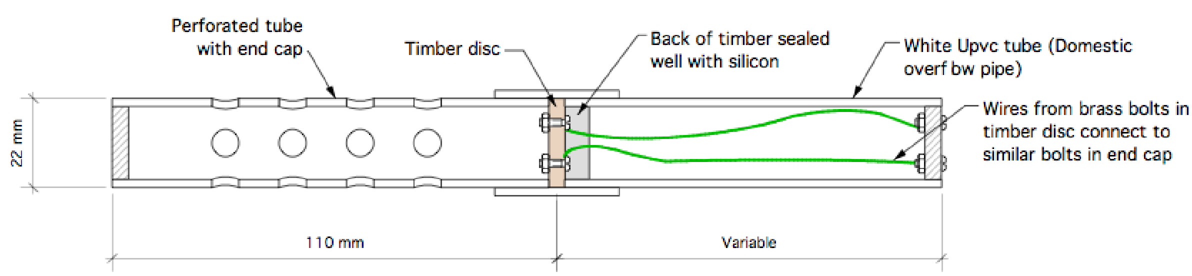

Figure 1: Section through the original timber-block probe as modified at Plymouth

The theory being that because the timber is in the same environment as the straw it will mimic the moisture behaviour of the straw. After a period of time the air in the perforated tube will be at equilibrium with the air surrounding the individual pieces of straw in the wall and the relative humidity of that air will be adsorbed by the timber disc to give it the same moisture content as the straw. A pair of wires are attached to small stainless steel or brass bolts fixed 12 mm apart in the timber disc and the other ends of the wires are attached to similar bolts fixed to the end cap of the tube. When inserted into the wall, a reading can be taken with a timber moisture meter from the bolts in the end cap, or a pair of flying leads can be taken to a central terminal block where more than one probe can be monitored.

Depending on the length of the different sections of the probe, and the number and spread of the perforations, the probes could be tuned to read the moisture content at different depths into the wall, and in the case of the Totnes house, the probes were used in pairs of one long and one short, inserted into the wall about 100mm apart thus measuring the moisture at two points, one close to the inside face of the wall, and one towards the outside. This would give an idea of the moisture gradient through the wall. The probes were used for the first year of monitoring until a Protimeter 'Balemaster' was acquired.

Figure 2: Protimeter 'Balemaster' in use

The 'Balemaster' is designed for use in agriculture, and consists of a 600mm long steel probe that can be inserted directly into the interior of a straw bale wall through a hole drilled in the outside render. The probe is attached to a meter that measures the electrical resistance at the tip and is calibrated to give a measure of the moisture content of wheat straw (Figure 2). Inserting the 'Balemaster' into the same places in the walls that contained the timber block probes showed significant discrepancies in the moisture levels recorded. With reference to the expected moisture content of a typical straw wall(Lacinski and Bergeron 2000) it seemed likely that the timber block probes were under-estimating the actual moisture levels. Therefore, whilst the study had shown the potential for the moisture monitoring of straw bale buildings using timber-blocks, further research was needed to improve their accuracy (Figure 3).

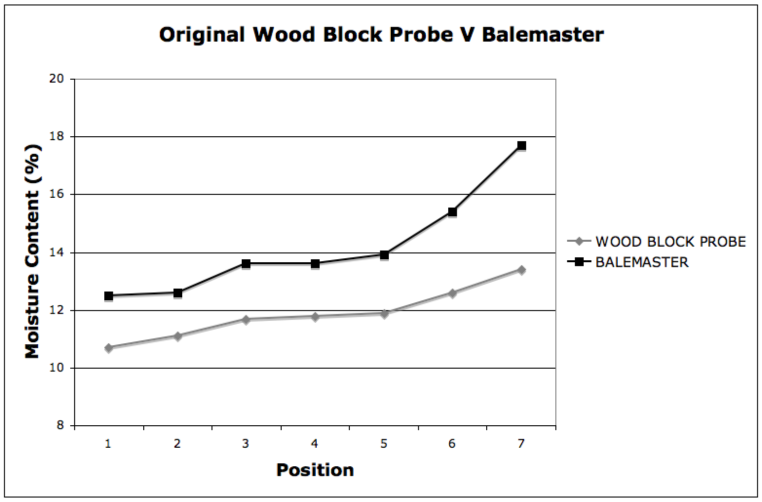

Figure 3: Graph illustrating the discrepancies between the original timber-block probes and the 'Balemaster'.

In January 2007 a full-time research project at the University of Plymouth commenced the process of designing and calibrating an improved timber-block probe. A series of three prototypes exploring the effectiveness of different configurations were constructed and tested in the lab and in the walls of the Totnes house

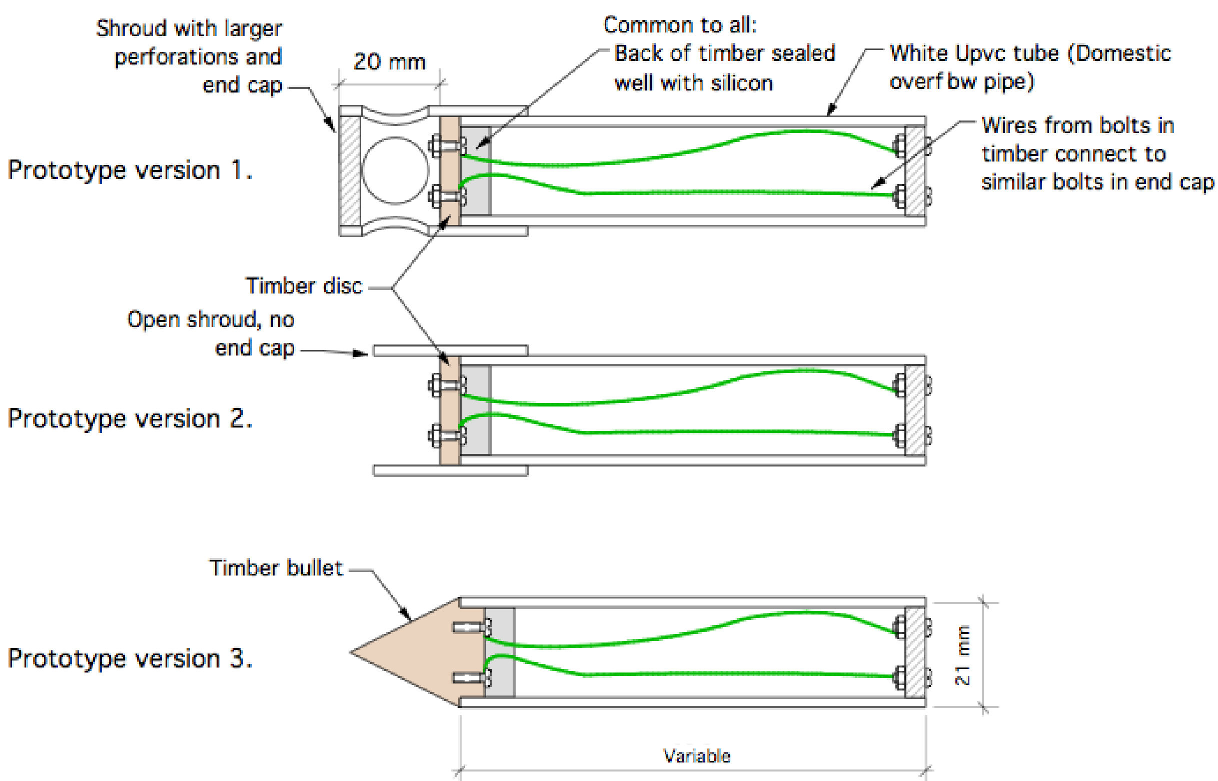

Figure 4: Prototypes for the improved timber-block probes

Version 1 has a simplified version of the originals perforated tube, but made shorter, and with larger holes, so the timber disc ‘sees’ a smaller volume of air, and the ratio of closed space to open space (through the wall of the tube) is greater. The second version still has a shroud, but it is simply a short extension of the tube, just enough to keep a physical separation between the timber and straw whilst still allowing a minimal separating air space. The third version changes the timber disc into a bullet shaped projection at the end of the tube that will force the timber into direct contact with the straw. This provides increased contact with the material being measured and was found in trials to more accurately follow the patterns of moisture concentrations in a variety of straw bale walls, almost exactly duplicating the readings given by the ‘Balemaster’ and gravimetric analysis, but unlike the ‘Balemaster’, these probes can be left in-situ. Used in pairs of one short and one long they can give an indication of the moisture gradient through the depth of the wall.

The ‘Balemaster’ probe was also used continuously at the Totnes Eco House, alongside temperature and relative humidity probes, combining to produce a detailed picture of the moisture performance of the straw bale walls.

Results

Sorption and Desorption Isotherm’s were created in the environmental chamber at the University of Plymouth over a period of four months. Specimens of previously oven dried wheat straw were placed in the chamber at a series of increasing relative humidities, and their moisture content established through gravimetric analysis. The results were plotted on a graph to create the Sorption Isotherm. Once the straw had achieved maximum moisture content at 98% RH, the process was reversed and a Desorption Isotherm could be plotted (2000).

The Isotherms were then used as a reference for calibrating the improved timber-block probes. Isotherms for four different species of timber were created and the species that most closely followed that of straw, both in moisture content at a given relative humidity and temperature, and having a similar lag time between changes in humidity, was found to be a hardwood called Ramin, which became the choice of timber for the new probe. The technicians at the University of Plymouth produced a batch of 48 new probes, and all the probes produced were calibrated in the same environmental chamber. Because the Isotherm for Ramin had already been created, a single reading at 90% RH was all that was required to check their accuracy.

While the long term monitoring of the house continued, a series of tests were undertaken to compare the newly calibrated timber-block probes with the ‘Balemaster’, which had also been calibrated through gravimetric analysis. It can be seen from the graph (figure 5) that the two traces almost exactly overlap, confirming the accuracy of the new probe.

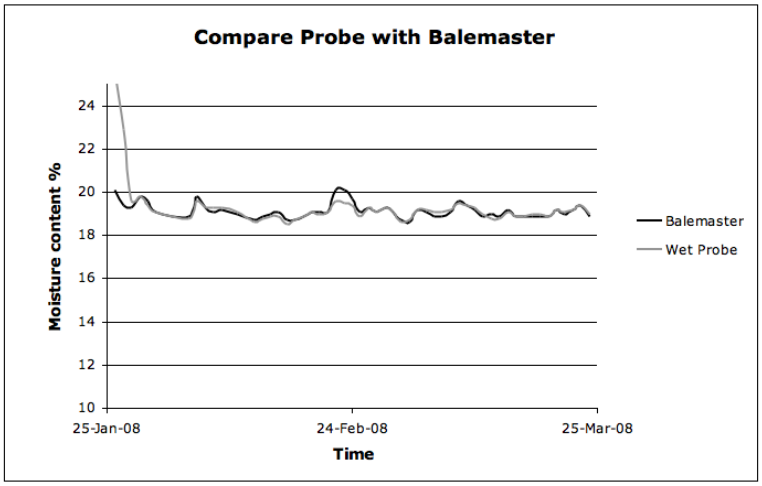

Figure 5: Graph showing results of comparison between the improved timber-block probe and the 'Balemaster'.

In looking at the moisture performance of straw bale walls, one of the most pressing questions is to establish a sensible safe maximum for moisture content in the wall. In the straw bale building community there is a received wisdom that the safe maximum moisture content for straw is 25%(Magwood and Mack 2000). This research confirms that a 25% maximum is a sensible upper limit for long-term moisture content in a temperate maritime climate such as that enjoyed by most of the UK. However, there are two caveats to add:

- This research project has shown that short-term exposure to higher moisture levels in a straw bale wall does not automatically lead to serious degradation as long as the levels do not exceed 37%, the capillary saturation point;
- If there are long-term moisture contents recorded of around 25%, then there is likely to be a problem with the construction of the building.

The capillary saturation point is the maximum amount of water that the straw can adsorb from the atmosphere in the form of water vapour. It represents the point at which the molecules of water vapour contained in the capillaries of the straw would start to combine to form water as a liquid. The sensible maximum atmospheric relative humidity for experimental purposes is around 98%, and at this point, the moisture content of straw is 37.6%; this is the capillary saturation point, and if the measured moisture content goes above this for even relatively short periods, then degradation of the straw is almost inevitable. The capillary saturation point represents the point at which the straw turns from damp to wet (Straube 2006).

This research shows the expected moisture content on the outside of a well-built and maintained wall to be between 15% and 18% depending on the local environmental conditions; readings will be higher on a wall that faces the prevailing weather, and lower in a more sheltered situation.

Figure 6: Parapet capping of a straw bale external wall showing where a drip edge had been badly executed.

At the Totnes Eco House there was an opportunity to record the results of a high build up of moisture. In 2007, measurements taken with the ‘Balemaster’ showed that one corner of a ground floor bedroom of the house was giving readings approaching 37%, where the bedroom next door had a maximum of 18%. The problem was traced to a badly executed drip detail on the parapet capping of a section of the straw bale wall (figure 6). The final coat of lime render had mistakenly been built up to fill the space behind a preformed drip and the wall surface behind it, creating a route for surface rainwater to penetrate into the interior of the wall. The defect was immediately fixed with the addition of a gutter around the parapet, and a series of detailed readings were taken at different heights and depths through the affected wall section.

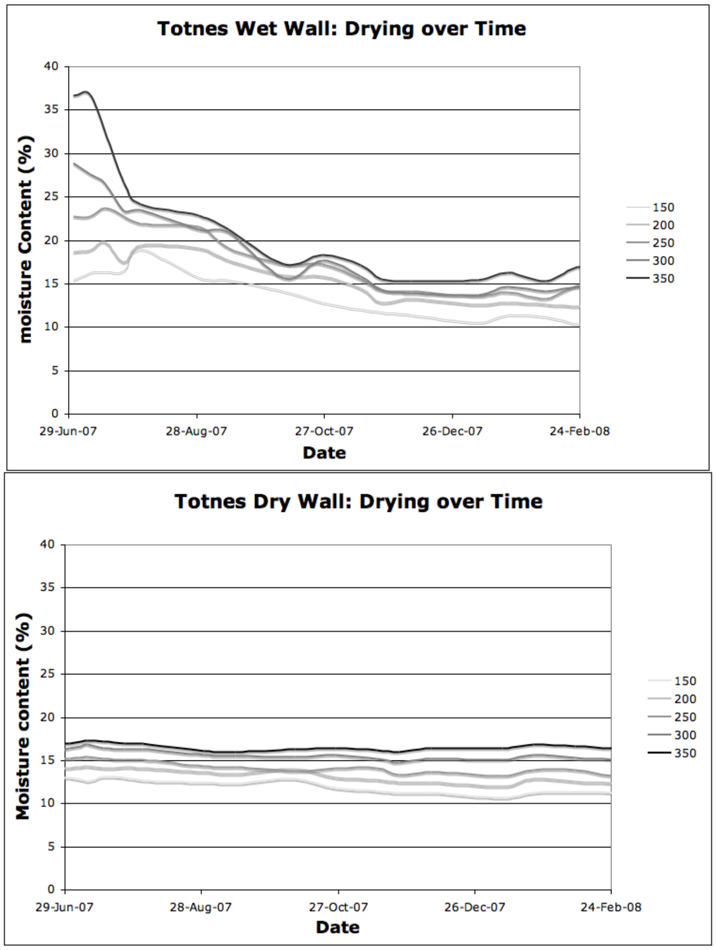

Figure 7: Graphs showing comparative readings from the bottom of the wet and dry walls.

The graphs in Figure 7 show comparative moisture measurements of the exterior walls of the two adjacent rooms during the drying out of the wet wall between June 2007 and February 2008. The measurements were taken at 50mm intervals through the wall from a depth of 150mm to 350mm, starting from the inside face. The drying process went through two distinct phases. During the first five weeks the outside of the wall (the dark trace on the graph at 350mm) is drying back fairly rapidly, while at the same time the trace nearest the interior of the wall is showing the opposite trend. This seems to indicate that the vapour pressure is equalising across the whole wall causing the excess moisture to spread itself more evenly through the wall. The second phase takes us through to November 2007, and shows the whole depth of the wall drying out at a similar rate until it reaches a level of moisture content comparable to the dry wall shown on the right, and indicative of the expected levels in a lime rendered wall, with the spread of moisture going from 12% on the inside to 16.0% on the outside. The graph of the dry wall (on the right), although appearing almost flat compared to the wet wall, shows that whilst the outside of the wall stays at around 16.5%, the inside of the wall, even eighteen months after the house was completed, is still gradually drying back from 13.0% to 11.5%.

Effects of a Timber Rainscreen at the Totnes Eco House

Another interesting result of the monitoring of the Totnes Eco House is a demonstration of the effectiveness of a simple timber rainscreen. On the South-East elevation of the house, moisture readings were taken in the same orientation behind two different finishes, allowing a comparison to be made (Figure 8).

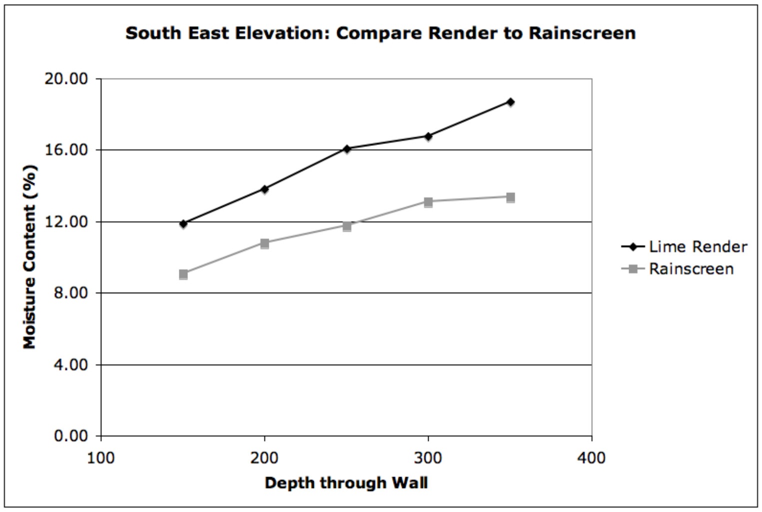

Figure 8: Readings of moisture content from the same position on the ground floor (lime render) and first floor (timber rainscreen) on the Southeast elevation of the Totnes Eco House taken on the 8th of November 2008

The outside of the straw bale wall on the first floor has a single 10mm coat of render, an air gap of 25 mm, a breather membrane, another air gap of 25 mm and finally the cedar rainscreen which is 18 mm thick; leading to an overall exterior wall thickness of 468mm. On the ground floor the straw is finished with the same three coats of fat lime render on both sides. As in the earlier graphs, the straw in two of these walls was measured at 50mm intervals through the wall, starting at a depth into the wall of 150mm. The of results for the South-east elevation taken on the same day show the difference in moisture content between the render and the rainscreen cladding reaching 3.8%. There are other factors influencing the readings, such as distance from the ground, and the fact that the water running off the rainscreen cladding is likely to be falling on the render below, but other buildings measured during this research indicate that they are a fair representation of the reduction in moisture afforded by the use of rainscreen cladding.

Conclusions

This research has enabled the development of an improved moisture probe that is cheap and easy to produce, and that can be left in-situ for the continuous monitoring of the moisture content of straw bale walls. Although more sophisticated devices such as relative humidity and temperature probes can be used, these timber-block probes can be produced in large numbers, and in the latest phase of this research, 48 sets of the long and short probes have been installed in a range of straw bale buildings that are being used for a variety of different forms of habitation. The results of one-year's monitoring of these eight case study buildings will be complete by the end of February 2010.

The long term monitoring of the Totnes Eco House has shown the ability of a straw bale wall that has been subject to moisture levels well in excess of established ‘safe’ maximums to successfully dry out with no apparent damage to the straw, with the proviso that the moisture levels do not exceed the capillary saturation point of around 37%.

The moisture behaviour of these straw bale walls also shows the critical importance of the use of hygroscopic finishes that will allow moisture vapour to travel safely through the wall, and encourage any excess to escape from the interior of the wall, although the measurements have shown that the complete drying of a straw bale wall can continue over at least two years.

This paper has provided further evidence to support the use of straw bale construction in the UK. Although a properly detailed and applied finish of fat lime render of 25mm can be considered adequate protection for most straw bale walls, where a building will be exposed to prolonged periods of driving rain there is no doubt that a vented timber rainscreen can significantly improve the performance of this form of low energy wall construction, thereby increasing its viability in the temperate maritime climate of this part of the world.

Acknowledgements

This research is partly supported by Great Western Research, The Ecology Building Society and The National Non-Food Crop Centre.

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PERSONAL EDUCATION FOR SUSTAINABLE DEVELOPMENT: THE WAY FORWARD FOR SUSTAINABLE CONSTRUCTION?

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Education for Sustainable Development is a key driver for all higher education disciplines and particularly relevant in the education of future construction professionals. While there is a natural tendency for educators to focus on the scientific and technological aspects of sustainability and sustainable construction, this approach will not necessarily maximise the positive contributions professionals have to offer because it does not address the intrinsic motivations people need if they are to embrace the positive changes sustainability requires. This paper reviews the arguments on role of technology as a sustainable 'solution' and introduces a new initiative developed at the University of Plymouth for engaging learners directly with the sustainability agenda.

Key words: Sustainability, technology, personal behaviour

INTRODUCTION

As the evidence continues to mount about species loss, resource depletion and pollution, a stark reality is coming into ever-sharper focus; the model humanity has been using since the Industrial Revolution to better itself, what Dopplet (2008) describes as the *'Take-Make-Waste'* phenomenon, is unsustainable. Simply put, this means is that we are depleting natural resources faster than they can be replenished. Human society can respond by changing its ways voluntarily or we can carry on as we are until the burdens we impose on the environment become so great that nature is no longer able to support our civilisation. Thus, change is inevitable. Common sense dictates that the preferred option must be to implement change voluntarily, the problem is, most people are highly averse to change, so although progress is being made, it is painfully slow. The question for construction professionals is how can we and our industry contribute to delivering the fundamental changes needed to avert or at least reduce the impact of what many believe to be a distinctly unsustainable future.

It is generally accepted that the built environment has major impacts on humanity's social, environmental and economic performance (Table 1).

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Table 1 Key sustainability impacts of construction and the built environment

Social	Environmental	Economic
Provides basic shelter	Accounts for half of all energy use	Employs 110 million people
Provides cultural spaces	Responsible for 40% of resource use	Accounts for 70% of all man-made wealth
Creates the basis for social and manufacturing capital	Responsible for land use	Between 8 and 10% of GDP

(Sources: Du Plessis et al 2001, piv; Du Plessis 2002, pp15-16; Edwards 2003)

Bearing in mind Table 1, it is unsurprising that virtually all the major professional bodies require elements of sustainability to be embedded within accredited built environment education programmes (Table 2).

Table 2 Key Professional bodies – input to education for sustainability

Discipline/ professional body	Curriculum influence	Sustainability focus
<u>Architecture</u> Royal Institute of British Architects	Outcome based “Criteria for Validation” used in accreditation visits	2002 Criteria includes design-specific social, cultural and environmental learning outcomes, and specific skills requirements
<u>Construction Management</u> Chartered Institute of Building	Requirement to comply with 80% of outcome based *Education Framework*; with accreditation visits	Framework refers to environment aspects and broad social, ethical and cultural issues. Some specific skills requirements relate to sustainability.
<u>Engineering</u> Institution of Civil Engineers Institution of Structural Engineers; Chartered Institution of Services Engineers	ICE/CIBSE/IStructE published curriculum expectations through ‘Joint Board of Moderators’, with peer review and departmental visits	Need for sustainable development delivery in degree programmes with detailed lists for knowledge, skills and attitude development published July 2005
<u>Surveying</u> Royal Institution of Chartered Surveyors	Curriculum expected to support sustainability as a professional competence.	RICS announces need to address education for sustainability No other formal requirements.
<u>Planning</u> Royal Town Planning Institute	2001 Education Policy Statement issued as guidance	Sustainability, social, economic and environmental contexts and appropriate knowledge themes referred to.

(Adapted from Murray & Cotgrave 2007)

The University of Plymouth has been responding to the drive for sustainable construction for fourteen years, delivering professionally accredited, sustainability-themed surveying and construction degrees. The aim of these degrees is to deliver environmentally cognate construction professionals to industry by integrating environment-related knowledge and skill themes integrated right across the curricula. With the agenda for environmental education evolving into a drive for *education for sustainable development* (ESD) (UNESCO 2003), Plymouth's construction degrees underwent a detailed, structured audit of sustainability content in 2005, which assessed all the modules against a schedule of over

100 knowledge and skill themes derived from an extensive literature review. The audit confirmed that 80% of the modules included applied, or generic elements of sustainability (Murray *et al* 2007), although some updating was required. The science, technical and professional elements of sustainability were well represented in the delivery of the curricula, however the audit revealed that wider generic aspects of sustainability were not covered and there was no consideration of the role of personal values or human behaviour. The teaching team concluded that the degrees appeared to adopt a sound technical approach but could not be said to fully embed sustainability literacy because they did not engage learners with sustainability at a personal level. Bearing in mind that sustainability literacy is a combination sustainability-related knowledge, skills and values (F4F 2002, Dyer and Selby 2004), research was undertaken following the audit to examine how a more 'personal' approach to producing sustainability literate construction graduates that places due emphasis on the role of the individual in helping realise a sustainable future could be realised.

CONSTRUCTION IN CONTEXT

In the early 1970s, scientists Paul Ehrlich and John Holdren devised a simple equation called the IPAT identity to represent the impacts human activity has on nature (see below).

$$\mathbf{I = P \times A \times T}$$

(I = impact; P = population; A = Affluence ; T = level of technological advance)

(Source: Ehrlich and Holdren 1972)

IPAT suggests that total human impacts increases with rises in population, affluence (because consumption rises with increased income) and technology (on the assumption that access to and advances in technological increase resource use and pollution). There is some historical basis to IPAT, which authorities such as Professor Sing Chew have documented in the context of the decline of pre-industrial civilisations such as the Sumerians (900BC), the Romans (100AD) and the Mayans (1200AD) as a result of the environmental problems they created. As these societies grew and flourished, their technologies developed and their population grew, increasing demand for the available natural resources, particularly fuel, which was normally wood. The resulting deforestation not only eventually stripped away the primary source of energy; it led to the loss of fertile soil due to erosion. Applied to the 21st Century, IPAT indicates untenable position where all components in the equation are advancing simultaneously. As Figure 1 demonstrates, there is no doubt that the human population is growing at an alarming rate.

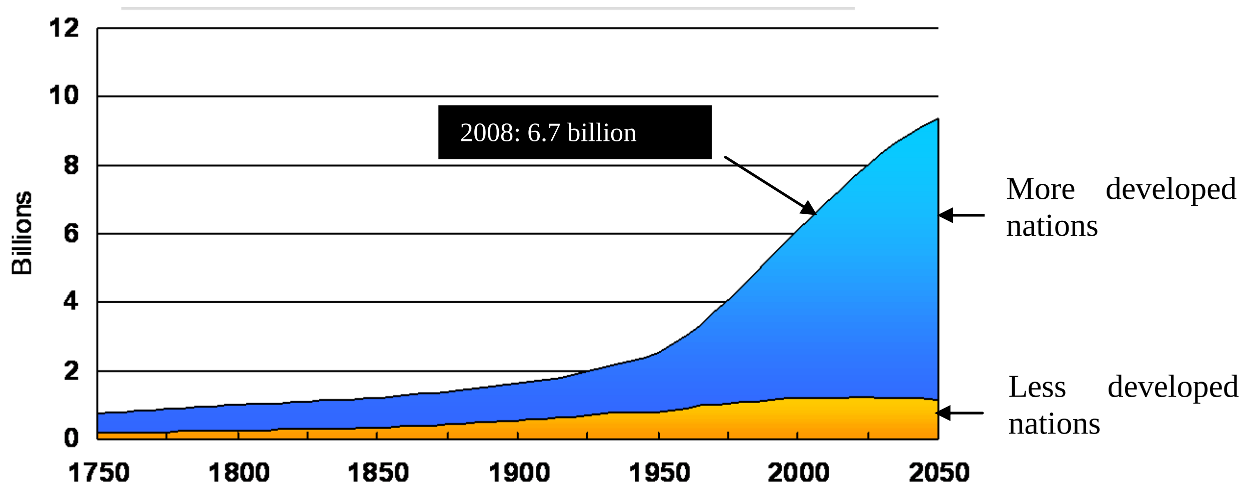

Figure 1 World Population Growth to 2100
(Source: WRI and Population Reference Bureau 2006)

According to the UN and the Population Reference Bureau, population growth will continue, because global mortality rates have declined dramatically due to advances in medical science, while fertility rates, the number of children born per woman, remain stubbornly high. This is particularly evident in less developed nations where access to education and family planning is poor and fertility rates can be as high as 6 compared to around 2 in wealthier parts of the world. Global affluence is also set to increase as previously underdeveloped nations, such as China and India, industrialise at a frantic rate to lift their people out of poverty. According to 2007 World Bank Development Indicators, only around 20% of the world's people live in wealthy countries. Of the rest, around half live below the $2.50/day international poverty line and 1.4 billion of these experience *extreme* poverty (poverty that kills) while the remainder live on less than $10 a day. Bearing in mind it is a natural human instinct to desire a better life; there are over five billion humans (and rising) who aspire to raise their living standards. Lifting them out of poverty is a just priority, but commonsense, and IPAT tells us that raising living standards of living worldwide to 'western' levels is likely to have catastrophic environmental implications as the take up on resource hungry technologies spreads. The construction industry makes a positive contribution in raising living standards by providing the shelter and facilities people need to live and work in ever-increasing comfort. But as it is also notoriously resource inefficient and cannot curb population growth, perhaps its best role lies with the take-up of new and more efficient technologies to reduce its burden on the planet?

TECHNOLOGY - THE ANSWER?

Without doubt, advances in medicine and engineering have enhanced the material wellbeing, mobility, health and longevity of people right across the world. Products like the automobile, computers and mobile phones define the times and many people believe that cleaner, more efficient, more innovative technologies will solve the world's 'sustainability' problems. Appealing as this possibility might be, technology has a dark side too, evidenced by weapons of mass destruction that have the potential to destroy civilisation many times over being one example. Clearly, technology has to be harnessed for good, as it could be in a construction context. Even then, can it be relied on to safeguard our future?

Politicians and the media are attracted to techno-fixes such as giant solar shades in space and artificial volcanoes to mitigate global warming, particularly when they are expounded by authoritative bodies like NASA's Institute for Advanced Concepts and Britain's Royal Society. In the construction arena, governments across the world are backing the construction of new 'Eco Cities' as high profile representations of their commitment to sustainability and, purportedly, to inspire sustainable lifestyles. Such hi-tech solutions seem to appeal because they appear to be exciting, quick-fix solutions. But appearances can be deceptive and account must be taken of the huge levels of effort and finance needed to develop them. Given the complexity of the problems we face, is it likely that there are single 'quick-fix' solutions that will get us out of trouble? Maybe not, yet technology offers much more than hype.

Engineering innovations have an outstanding record of improving industrial efficiency. Year-on-year, engineering technologists find ways of reducing pollution and increasing energy efficiency. Dupont reduced greenhouse gas emissions by 72% between 1991 and 2007 and Dow Chemicals recorded 22% gains in energy efficiency between 1994 and 2004 while confidently committing itself to a further 25% reduction by 2015. There is no shortage of proof that industrial efficiency can be vastly improved. The Rocky Mountain Institute introduced an initiative in 2003 called *Factor Ten Engineering* (10xE) to transform the resource productivity of engineering processes by a factor of ten through education and shared innovative practices.

New technologies do also offer direct solutions in the form of renewable energies (Figure 2). Within the renewable energy sector, new products are continually being developed such as thin-film photovoltaic panels, which have the potential to make available cheap and efficient solar power in the future. The renewable energy industries also demonstrate how technology can contribute to socio-economic development by providing jobs. 2008 figures published by the World Watch Institute show that 2.3 million people were employed globally in the renewable energy industries, and in Germany job growth in renewable technologies is expected to triple by 2030.

Despite these benefits, the role of technology as a primary means of driving sustainable development is questionable. Firstly, new technologies bring with them unintended as well as intended outcomes. Secondly, efficient technologies are only helpful if they are taken up and used effectively and thirdly, their environmental performance can be weak when examined closely. Furthermore, single-mindedly focusing on technology could distract attention away from the urgent need for systemic change.

The potential of renewable energy technologies

Solar hot water systems could provide half the world's hot water

☼

Solar cells could Account for 10% of the USA grid by 2030

☼

Solar power plants located in southern US states could produce seven times the US electricity capacity

☼

Wind power could provide 20% of world electricity, while off-shore wind could serve all of the EU's electricity needs

☼

Biomass could replace a third of US oil use

☼

Renewables have the potential to provide up to 50% of world energy in second half of the 21ST Century

Figure 2 Renewable Energy potential

Sources: UNDP (2000) cited in Worldwatch Institute's State of the World 2008
UNDP (2004) World Energy Assessment 2004 Update
Image: Translucent PV panels, Bedzed, England; courtesy Brian Pilkington

1. Unintended outcomes

All human activity has intended and unintended outcomes, which may be foreseen, unforeseen, helpful or unhelpful. *Aspirin* was developed over 100 years ago from the bark of the Willow tree as a pain killer. Since then, it has proved helpful in staving off life-threatening conditions including heart attack, stroke and bowel cancer, all positive unforeseen, unintended outcomes. Particularly destructive unintended outcomes can arise when poor design and human error combine, as occurred during the events that started at 01.23am on the 28 April 1986, 70 miles from Kiev. This was Chernobyl, the world's worst nuclear accident. It killed at least 50 people directly and irradiated between 9000 and 930000 more, depending on who one believes (the official Chernobyl Forum or Greenpeace). Over two decades later, Chernobyl is still the most radioactive place on Earth and will remain uninhabitable for hundreds of years. The causes of the disaster are shrouded in mystery, but relate to human error in both the design of the plant and the emergency contingency procedures in place at the time. No one intended the accident to happen, and evidently very few people foresaw it, but its social and environmental implications are incalculable.

2. Take up

Making better technologies available does not mean they will be adopted. The carmaker Volkswagen unveiled their *1 Litre Car* in 2002, which can travel 100 Km on a single litre of fuel and achieve 285mpg. There is prestige to be gained in developing such headline grabbing technologies but to have any real impact; manufacturers have to invest in bringing them to the everyday market at prices that ordinary people can afford. Even then consumers have to be persuaded to purchase them, which, as history suggests, is not always easy. In the early 1990s, Sports Utility Vehicles (SUVs) accounted for 7% of USA vehicle purchases. The following decade witnessed a vast increase in environmental awareness, yet by 2004 sales of gas-guzzling SUVs had rocketed, representing 56% of the car market. Although SUVs were known to be more polluting than standard cars, they became the vehicle of choice because fuel in the US was so cheap that fuel efficiency did not affect purchasing decisions. A second reason relates to consumer values. According to a 2005 survey by the motoring organisation Kelley Blue Book, purchasing an SUV was seen as '*patriotic*' and a separate Time Magazine/CNN survey report suggested that consumers perceived SUVs to be *safer* than standard vehicles, despite statistics demonstrating otherwise. Only when fuel prices to doubled did SUV sales decline. In the construction context, lessons can be drawn from the introduction of gas condensing heating boilers in the UK in the 1980s. Standard boilers at the time were around 65% efficient, while condensing boilers could achieve efficiencies approaching 95%, offering greatly reduced energy consumption, running costs and pollution. While condensing boilers were 10 to 15% more expensive to purchase than standard boilers, their payback period was typically five years or less. Logic suggests that condensing boiler sales should have spiralled but they did not. According to the Building research Establishment, by 2001 condensing boilers still commanded less than 2% of the domestic boiler market, a istaution that proved difficult to change despite the government tried offering financial grants to off-set the increased purchase cost. Twenty years later, regulations were imposed requiring all new and replacement boilers to be condensing units; an example of late, but appropriate and effective government intervention.

3. Sustainability performance

Technology induced efficiencies may not make consumerism sustainable. Eric Niemeyer in *Weak vs. Strong Sustainability* highlights that while efficiency gains will reduce pollution and energy burdens per unit manufactured, the net ecological impact of industry is likely to rise by factors of tens, even hundreds because, as incomes rise manufactured products become available to increasing numbers of people, particularly in developing countries. By way of example, IBM's 2008 *Global Innovation Report* anticipates a doubling of the current twenty million cars in China by 2020. In theory, rises in income should decrease environmental damage because as countries become wealthier they can afford to invest in cleaner, more efficient industrial technologies. While this may have occurred in western nations, it took many decades to reap the benefits. Many less developed countries will require substantial financial support if they are to acquire state-of-the-art sustainable technologies to drive their development.

All industrial outputs and processes embody ecological impacts that are difficult and time consuming to evaluate because they occur over the entire product life cycle. Every stage of a product's life, from acquiring the raw materials to its final disposal consumes resources, emits bi-products and creates social impacts . These embodied impacts can be unexpected and worrying. Information Technologies deliver a positive environmental contribution by helping make processes and activities more efficient but also bring hidden costs. A 2004 study on the embodied energy within Personal Computers uncovered that 83% of their total energy consumption is accounted for in its manufacture, before it even arrives on its user's desk. Bearing in mind that the average life of PCs is three years, they are much more energy and carbon intensive products to use than they first appear. IT products mirror construction in being absurdly wasteful; according to IBM (2008), one tonne of electronic scrap from PCs can contain more gold than seventeen tonnes of gold ore.

4. Technology as a distraction

A blind belief that technological approaches alone will suffice is likely to encourage people to wait for 'better' technologies to arrive, meanwhile changing nothing. This approach neatly passes responsibility for action onto others (manufacturers, designers, governments, etc.) and therefore promotes the maintenance of the status quo. Technological approaches can distract in other ways too. For example, there is little evidence that technology-based approaches such as the construction of hi-tech Eco-cities will necessarily deliver net benefits. The Eco-cities being developed in countries across the world involve massive new construction programmes that will consume materials on a huge scale (box right). The implications are that we could cover the world with Eco-cities and simply make our problems worse rather than better because of the scale of the sustainability impacts the resource use entails. Also, new buildings in many countries represent a tiny proportion of the overall building stock, it can be argued that the Eco-city phenomenon distracts thinking and investment away from the real need: to radically upgrade the sustainability performance of the world's existing buildings.

Table 3 Typical resource input into new housing 2006: (Based on Building Research Establishment 2006 figures)

100000 New UK Houses:
1.2 million m3 of spoil
15.6 million concrete blocks
69.4 million clay bricks
1.5 million m2 Gyproc
2.7 million m2 glass
5600 m3 lumber
750000 litres of paint
500 km of roadway

Overall, there is no doubt that new, more efficient and effective technologies have an important role in realising a sustainable future, they can only be half of the answer. If so, the other half must relate to how people live and work; human behaviour. It is easy to look to institutions, governments and corporations for change, but all organisations require the buy-in of their internal and external stakeholders to move forward. To achieve this, individuals whether employees, customers, constituents or just citizens need to accept that it is our current way of thinking that is driving the unrelenting, unsustainable consumption of planetary resources. Therefore, to live and work sustainably, we have to change the way we think to change the way we act and this is particularly important in industries like construction which have so much to offer

THE PERSONAL APPROACH

Knowledge and skills can 'equip' construction professionals to act sustainably within and outside work, but will not necessarily motivate or empower them to do so. The personal approach to sustainable development, or sustainable construction, is about securing a level of personal engagement that motivates and empowers the individual to recognise the opportunities that arise and to act upon them with confidence and competence (Figure 3).

Figure 3 The Personal Approach to Education for Sustainable Behaviour

To deliver this approach, staff at the University of Plymouth have developed a suite of new activities that focused on the promoting sustainability thinking by helping learners reflect upon their values, attitudes and beliefs in the context of sustainability generally and in the workplace in particular (Figure 4)

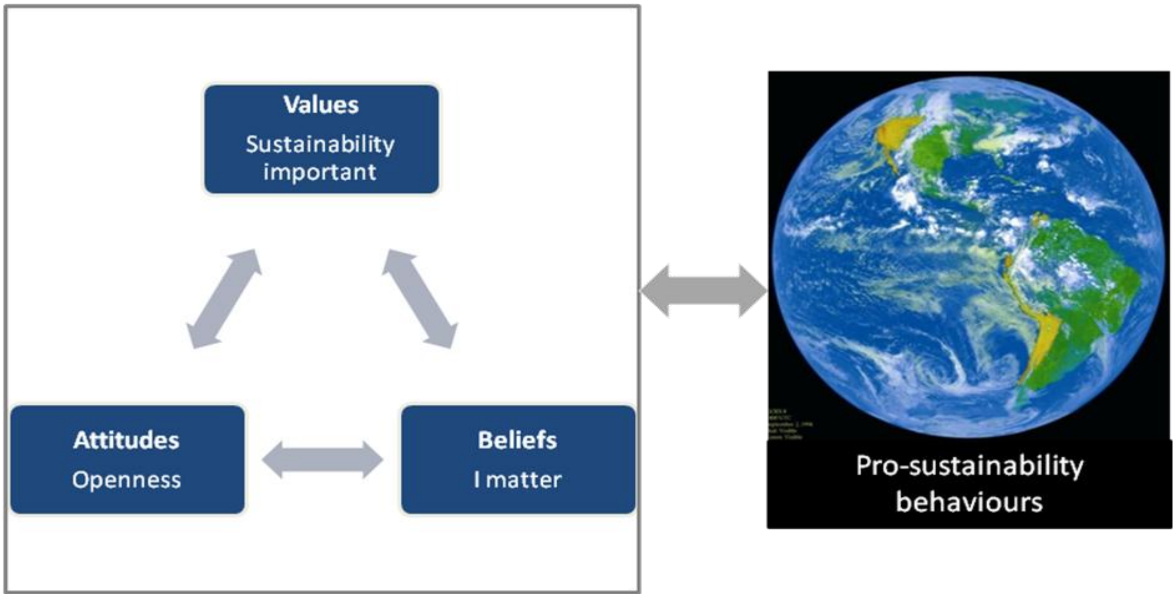

Figure 4 Values attitudes and beliefs for sustainability thinking
(Image source: NASA)

The activities take place over a six hour period, usually in one event, and are designed to be open-ended, thought-provoking and confidence building (Table 3).

Introduction	Setting the context	1400
Activity 1	Personalising sustainability (Metaphors/Definitions)	1415
Activity 2	Connecting with sustainability (Image Ranking)	1435
	Comfort break	
Activity 3	Eliciting and understanding personal values	1525
Activity 4	Reflecting on attitudes (NLP Perceptual Positions/images)	1600
	Comfort break	
	Discussion on role of caring and compassion	1700
Activity 6	Personal Empowerment (Circles of Influence 1)	1730
	Buffet	
Activity 7	Professional Empowerment (No barriers thinking)	18.00
Activity 8	Integration: Linking knowledge, skills and values	18.30
	Concluding discussion, feedback	19.30

Table 4: Typical activity schedule for Sustainability Training

The exercises involve the extensive use of imagery to engage participants and involve the adaptation of Neuro Linguistic programming principles to enable participants to identify and reflect upon their attitudes to specific sustainability issues. The theoretical basis of the training is reported in Murray and Murray (2007) and Murray, Murray and Brown (2007). To date, over 500 individuals have undertaken the full six hour training or two hour tasters (Figure 5) with structured feedback being overwhelmingly positive (Murray and Murray 2007) and eliciting enthusiastic open comments:

"Transformational"
"A great thing to do; motivated me"
"Builds confidence"
"Fantastic, engaging us to be effective and involved."
"Made me think more deeply / broadly"
"Helped consider own/others' values & attitudes"
"Gained a better understanding"
"Very inspiring"

The training became compulsory for all undergraduate and postgraduate construction degrees at Plymouth from 2008, on the express recommendation of 100% of the 63 students involved in the early field trials that took place in 2006/7.

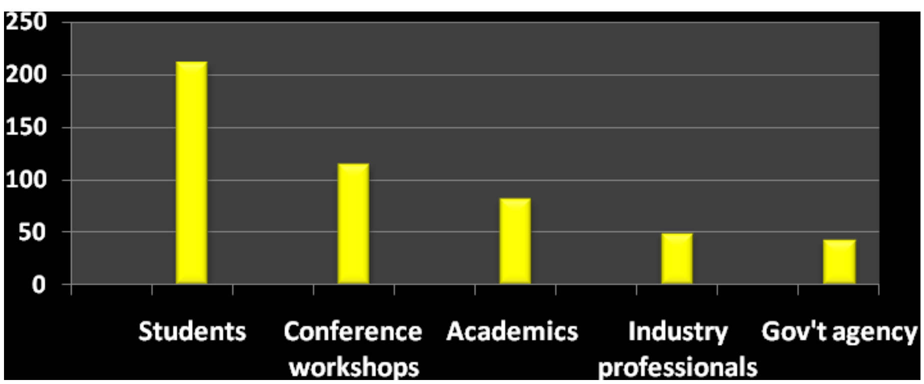

Figure 5 Take up of Sustainability Training to December 2009

LOOKING AHEAD

To take the PESD approach forward, a new interactive book is proposed *Personal Education for Sustainable Development,* which extends the sustainability training concept in more detail in book form. Measures are currently being taken in the form of values and attitudes surveys taken by participants before and after the workshops to explore their impact. In addition, follow up workshops and other vehicles are being explored to build upon the significant promise that the training offers, not only for construction students but for learners from other disciplines and professionals.

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MANAGING KNOWLEDGE TO MAKE SOCIAL HOUSING REFURBISHMENTS MORE SUSTAINABLE

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The construction industry has an important role to play in the development of a sustainable society. This paper presents sustainable refurbishment of the existing building stock as the most sustainable solution compared to demolition and new build. Knowledge management systems are presented as effective tools to increase the sustainability level of refurbishment projects and the social housing sector is identified as the UK construction industry sector the most able to develop sustainability initiatives. The paper concludes by presenting the subject of an ongoing PhD research at Glasgow Caledonian University which is the development of a knowledge management framework aiming at improving the sustainability level of social housing refurbishment.

Keywords: Knowledge management framework, Refurbishment, Social housing, Sustainability.

THE NEED FOR A CHANGE

During the last 150 years the urban population has significantly increased (Herkert, 1998). This demographic change resulted in a dramatic shift in the way humans were to fit into the ecosphere (Rees, 1999 cited in Cruickshank and Fenner, 2007). In fact during the 20th century, the human population quadrupled to almost 6 billion; the energy used increased 16-fold; industrial production grew 40-fold; water usage increased 9 times; fishing rose by a factor of 35 yet fish populations declined (data from Lubchenco, 1998; McNeill, 2000; Myers and Worm, 2003). Important scientific publications provide evidence of land degradation and declining agricultural productivity (World Resources Institute (WRI), 1992; WRI, 1994), greenhouse gas emissions (European Institute for Urban Affairs (EIUA), 1993) and loss of biodiversity (Wilson, 1992).

The growing concern for the depletion of natural resources created the need for a new political discourse combining development and respect for the environment; so-called ‘sustainable development’(International Union for the Conservation of Nature and natural resource (IUCN), 1980).The sustainability concept gained international recognition at the World Commission on Environment and Development (WCED) with the production of the Brundtland report containing the following sustainability definition
“Development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (WCED, 1987).

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This broad definition is now deeply embedded in development policies across the globe (Carter and Fortune, 2008). However this definition's popularity is attributed to its ambiguity, appealing as much to those with a focus on the regenerative capacity of the environment as to those who focus on the potential for technological progress to adapt to changing conditions (Meppem and Gill, 1998). In fact more than 20 years after the WCED, the way how the 'sustainability concept' should be defined, interpreted and assessed still generates debates (El-Haram et al. 2007). As an illustration of these divergences, Pearce et al. (1989) listed over 20 possible meanings of sustainable development and Fowke and Prasad (1996) identified 80 sustainability definitions. The divergence of opinions suggests that sustainability is so broad idea that an universal definition cannot adequately capture all the nuances of the concept (Hill and Bowen, 1997). However, even if there is no consensus around the definition, it is generally accepted that the sustainability concept draws together economic, environmental and social objectives (El-Haram et al. 2007). It also refers to issues of technology, social cohesion, community sustainability, citizen participation, and lifestyles (Premius, 2005).

Despite a growing awareness of the western population of the sustainability meaning, researchers such as Rees (2009) argue that government sustainable directives and industrial sustainable innovations are not enough to reach the goal of a society based on sustainable environmental principles. Fast growing global populations and limited natural resources make the aim of reducing the human environmental damage inappropriate (Rees, 2009). Humans do not need to only reduce their impact on the environment but they must strive to totally eliminate it. This objective of 100% sustainable development might seem unrealistic but is actually the only option ensuring the survival of Humans on planet earth.

THE CONSTRUCTION INDUSTRY'S LEAD ROLE IN THE SUSTAINABLE REVOLUTION

According to Roodman and Lenssen (1994) one-tenth of the global economy is dedicated to constructing, operating and equipping homes and offices. These activities accounts for approximately 40% of the materials flow entering in the world economy, with much of the rest destined for roads, bridges and vehicles to connect buildings (Roodman and Lenssen, 1994). It is now recognised that the construction industry's negative impact on the environment is relatively important compared to other industries (Rees, 2009; Horvath, 2004). Therefore there is a need for a sustainable revolution throughout the construction industry where new buildings and refurbishments have for objective to make the built environment 100% sustainable.

In the UK, the government produced numerous forms of engagements and many policies (energy and fuel policy for example) in favour of sustainable development (Department of Energy and Climate Change, 2009). Technical advices have also been made available to households and businesses via agencies such as Building Research Establishment (BRE) or the Energy Saving Trust and Carbon Trust (Pickvance and Chautard, 2006). The UK government also tighten the building regulations and set an objective of zero carbon emission for new built in 2016 (Communities and Local Government (CLG), 2008a). However until now the UK government strategy has been unsuccessful and the majority of housing is still developed in an unsustainable manner (Hall and Purchase, 2006). Hall and

Purchase (2006) explained that government reliance on legislation (building regulations) is understandable due to the overreliance of construction professionals on building regulations but it can also be seen as an ineffective tactic since legislation alone does not change behaviour.

Paradoxically the construction industry is in a better position than many other industries to implement sustainable practices (Rees 2009). The Building and Social Housing Foundation (BSHF, 2002) claimed that the knowledge and technology required to produce sustainable housing was widely available. However many organisations feel that sustainability has no direct business impact and is not a mean of improving efficiency or value for money (Hall and Purchase, 2006). The construction industry also indicates a lack of 'sustainability demand' from end users (clients) and that sustainable practice can increase operating costs (BSHF, 2002; Department of Environment Transport and the Regions (DETR), 1999; Timkins, 2002).

Until now, the construction industry did not realise the extent of the situation. The challenge of the next decade will be to make the construction industry realise and respond to its environmental impacts. Moreover the important size and scale of the construction industry in the global economy is such that it could influence other industries toward a general sustainable revolution (Rees, 2009).

SUSTAINABLE REFURBISMENT

Sustainability incentives and recommendations concern all the construction industry but mandatory directives concern only the social housing new build which is a tiny part of the overall UK building stock (CLG, 2009). Moreover new buildings add, at most, 1% a year to the existing stock and the other 99% of buildings are already built and produce 27% of all UK carbon emissions (The Economist, 2007; Office of the climate change, 2007). To achieve the government's plan of 45% greenhouse gas emission reduction by 2020 and 80% by 2050, renovating the existing building stock must be a priority (Resource for Urban Design Innovation (RUDI), 2009). In fact Rees (2009) argues that in slow growing developed countries such as North America or Europe, new construction must be limited and efforts must be concentrated into refurbishment programmes of the existing stock.

Comparing energy aspect of demolition and refurbishment several studies concluded that refurbishment could reach the same target of energy consumption reduction more quickly and easily (Ireland, 2005, 2008; Yates, 2006, Sunikka, 2003). Power and Mumford (2003) also demonstrated that the argument of demolishing the least efficient part of the stock to replace it with new build could save more energy than a refurbishment was ill-founded. They argue that older, pre First World War properties are the least energy efficient but are often the easiest to renovate and make more efficient and concluded that there is almost an inverse relationship between the scale of current decay and neglect and the recycling potential of a housing area. Moreover refurbishment takes into consideration the social aspect by keeping existing communities (Power, 2008).

Many researchers acknowledge the fact that in the short term (10 years) refurbishment save more than new build in terms of carbon emissions (Ireland, 2008; Yates, 2006). However the Royal Commission on Environmental Pollution (RCEP, 2007) argues that in the long time frame (50 years) new homes with low energy use (‘zero carbon homes’) may eventually outperform refurbished existing property. This underlines the fact that only refurbishments with high sustainability level can save more energy than new build in the short and long term (Power, 2008).

Many European countries such as Austria, Switzerland, Germany, Netherlands, Denmark or Sweden already have developed strategies of sustainable refurbishment (Mickaityte et al. 2008). The German Programme ‘Zukunft Haus Pilot’ is an example of high sustainability standards refurbishment at a large scale. The programme involved upgrading and installing energy efficiency measures in 915 homes in 34 (mainly rented) blocks of flats across Eastern and Western Germany, mostly built before 1978. The main measures adopted were high insulation including external and internal cladding, high-quality glazing, efficient heating and energy systems, solar collectors for hot water, heat recovery mechanisms, and, where possible, the addition of south facing balconies (Deutsche Energie-Agentur GmbH (DENA), 2005). As a result of these measures, energy consumption was reduced by over 80% and the renovated homes became twice as energy efficient as the current German new build standard in spite of the much higher and more strictly enforced building standards in Germany than in the UK (Power, 2008). In the UK the Nottingham Eco-House demonstrates that energy consumption reductions of 85% are possible if all readily available efficiency measures are adopted (Power, 2008).

WHY SUSTAINABLE REFURBISHMENT IS SLOW IN THE UK?

The refurbishment process is a complex task and has been the subject of many studies. Researchers developed sophisticated decision support tools and models based on refurbishment alternatives to help stakeholders choosing the most appropriate strategy (Rosenfiels and Sholet, 1999; Alanne, 2004; Caccavelli and Gugerli, 2002). All these decision support tools and models intend to consider the social, economic and environmental aspects of sustainability and some of them consider the use of renewable energies (Dascali and Balaras, 2004; Zavadskas et al. 2006; Caccavelli and Genre, 2000). It can be summarised that the sustainable refurbishment of the current building stock has taken international scientists’ attention for years and many models and tools are now available (Mickaityte et al. 2008).

In the UK sustainable techniques, materials, decision making tools and other frameworks to help stakeholders refurbish in a sustainable way exist and are ready for practice. However the sustainable refurbishment is still at its infancy and good practice projects are still rare and isolated (Hall and Purchase, 2006). One of the main barriers to the development of sustainable practices resides in the construction industry incapacity to capture and share the knowledge created during best practices projects and constantly reinventing the wheel (Egan, 1998). Many studies (Egbu et al. 2003; Robinson et al. 2001;) identified the need to effectively manage knowledge as construction organisations often move from one project to another working with different partners and supply chains. During the last decades a growing number of knowledge management initiatives have been designed to improve the management of knowledge in the construction industry. The role of knowledge management as a source of potential advantage for construction organisations has been addressed by many researches (Kululanga et al. 1998; Carrillo et al. 2000; Patel et al. 2000; Suresh and Egbu, 2004). It is now accepted that knowledge management tools and systems can improve the construction industry efficiency by capturing and reusing the knowledge created from one project to another. Therefore knowledge management can also be considered as an efficient tool to manage sustainable knowledge of construction projects in order to implement sustainability in practice.

SOCIAL HOUSING LEADING THE CHANGE

In 2008, the UK government presented its objective of being among the European Unions leaders in sustainable procurement for the public sector and created a new Centre for Expertise in Sustainable Procurement (CESP) in the Office of Government Commerce (OGC) (Strategic Forum for Construction (SFC), 2008). Social housing is the largest sector of public procurement and is therefore at the forefront of sustainable procurement development (Hall and purchase, 2006). In fact social housing was already identified more than ten years ago in the Egan report (1998) as the sector most able to deliver improvements to the construction industry. Nowadays the social housing offers the most favourable condition in the UK construction industry to develop sustainable refurbishment.

Most Registered Social Landlords (RSLs) have relatively developed sustainability policies (Hall and Purchase, 2006). In addition, reports such as the Sustainable Housing Design Guide for Scotland provide a strong base of information for the design and management of sustainable social housings (Stevenson and Williams, 2009). Theoretically RSLs possess or can access to all the necessary information in order to realise sustainable refurbishment. However RSLs still struggle to implement sustainability at the project level (Hall and Purchase, 2006). Carter and Fortune (2008) argue that the sustainability level of a social housing project is influenced by two main factors: RSLs interpretation of sustainability policy and the procurement method. The work of Carter and Fortune (2008) focused on the RSLs interpretation of sustainability by developing a tool establishing the meaning of the sustainability concept at the project level. This tool helps RSLs to define and prioritise sustainability aspects of a project during the procurement. However the influence of the procurement method on the sustainability level of a project is still unclear.

CONCLUSIONS

There is a potential for knowledge management tools and systems to implement sustainability into construction project practices. The UK social housing sector capacity to innovate offers favourable conditions to develop knowledge management systems improving sustainability of refurbishment projects. Based on the literature review contextual background and the work of Carter and Fortune (2008) an ongoing PhD research at Glasgow Caledonian University is investigating the influence of procurement methods on the sustainability of social housing refurbishment projects. The research investigates the sustainability knowledge flow during the most common procurement methods of social housing refurbishment. The aim of the research is to develop a knowledge management framework aiming at improving the sharing of sustainability knowledge between the main stakeholders during the procurement of social housing refurbishment projects.

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SPORTS FACILITIES AND SUSTAINABLE DEVELOPMENT

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This research presents a preliminary data gathering on the Sports Facilities development in Malaysia. It was conducted a literature review and informal interviews with who are involved in the sports facilities in Malaysia. Increase in the amount of public money being spent on the sports facilities, as well as, increase in the number of sports facilities, necessitate demand to investigate issues surrounding sports facilities development in Malaysia. However, there is a current sports facilities construction boom universally. Initial results reveal there is a current interest in sports and sports facilities development in Malaysia however, the existing sports facilities are underutilized and there are not economic oriented. On the other hand, it is a new approach to the planning and design which is expected to guide the physical planning system focusing on the concept of sustainable development. Further research with provide information on the physical, economic and social impacts of the case study on urban development in Malaysian context.

Keywords: Sports Facilities, Development, Sustainable, Malaysia.

INTRODUCTION

In Malaysia, sports and sports facilities developments have improved rapidly over the past years. However, such improvements are inadequate compared to the overall development of sports at international level (National Sports Policy, 2007). Sport in Malaysia is only considered as an industry in the last ten years (Aminuddin and Parilah, 2008). Increase in the amount of public money being spend on sports facilities, as well as, increase in the number of sports facilities necessitate demand to investigate issues surrounding sports facilities development in Malaysia. The budget allocation for sports development, under the Ninth Malaysian plan, which is more than double that of the previous allocation, as well as the various plans for sports endorse the government's seriousness and commitment's towards the development of sports and a wave of sports investment in Malaysia (Malaysian Sports industry, 2008). Following this, the first sports school in Malaysia was established in 1996.

Universally, there is a current sports facilities construction boom. Sports facilities have changed through the years from functional facilities, adapted facilities, state-of-the art facilities to center of business and regenerating area facilities. However, over the past 20

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years investment in sporting infrastructure at national level in cities was not primarily aimed at getting the local community involved in sport, but was instead aimed at attracting tourists, encouraging inward investment and changing the image of the city (Gratton *et al.*, 2005).

Most of the literature on sports facilities come from the North American experience as their professional sports facilities are famous and popular. A lot of research has been conducted on sports facilities impacts both positive and negative. However, this is crucial in ensuring the long-term sustainability of such a huge investment.

This paper is based on reviewing the current literature and preliminary data gathering on sports facilities in Malaysia. It is structured as follows. The next section provides a brief overview on recent sports facilities. The third section concentrates on the sports facilities in Malaysia. The forth section aims to clarify the development considerations of sports facilities regarding to changes in the location, context, culture and usage. However, the fifth section considers on sustainable development in sports facilities. Finally, the conclusions address opportunities to achieve efficiency and enhancement for the future.

RECENT SPORTS FACILITIES

There is current sports facilities construction boom universally. These facilities are for hosting sports mega-events such as Olympic Games, Commonwealth Games or there are smaller scale facilities. The new Olympic movement was proclaimed in 1894 and held its first competition in Athens in 1896. Ever since then the sports have emerged in their modern forms and the sports facilities have evolved into one of the great public building forms of the twentieth century, regarded, at its best, as an essential and positive element of civic life (John *et al.*, 2007). Sport has transcended the boundary from being considered as an active leisure pastime to being recognized as having considerable social and economic influence in contemporary society (Davies, 2005).

There are various trends and rationales utilise to supports sports facilities development. Recent developments have witnessed the use of sports facilities as a force for urban growth. Cities have seized upon sports facilities as a means to redevelop specific district within their downtowns. However, one of the hallmarks of entrepreneurial city has been the construction of highly visible and very expensive special activity generators or flagship projects. Cultural sports and entertainment facilities are considered as catalytic facilities which receive public support in order to spur development in the immediate surrounding area (Sternberg, 2002).

At present, new generation of sports facilities can shape new cities or regenerate decaying areas of old cities. Proponents of sports investment have made different contents to define sports facilities role in cities, urban development, redevelopment, generation, catalyst, transformation, growth, revitalization, economic development, and community generation. However, they could provide better public subsidization. Following those, there are many researches to investigate their claims. But, although so many researches findings there are still an ongoing debate to build new sports facility with public funds (Sam and Scherer, 2008). It is due to requirement of huge money for construction, almost certainly with substantial public investments, and which involved too much money compared to the cost benefit analyses. There are also needs for ancillary construction that are often built at public expense with every provision of a new facility. In addition, there is a high cost for maintenance and the truth is that it is now very difficult for a sports facility to be financially viable without some degree of subsidy.

There are a wide range of positive and negative impacts that sports facilities construction have on their surrounding areas and wider cities. They may have political, economical, social, physical, legal, environmental, and safety impacts. However, they require huge public investment and whether there is enough justification for their funding. Generate new construction in the district, reuse of vacant building, changes in land use, and spin-off development are examples of physical impacts. Further, there are abilities to provide substantial social benefits. They might create community, improve interaction, provide recreation, intangible benefits, and alleviate deprivation. In addition, improve transportations lead to benefits for local communities. On the other hand, congestion, litter, traffic, vandalism, noise, and wrong kind of clientele are some kinds of negative impacts that sports facilities generate on their surrounding areas.

SPORTS FACILITIES IN MALAYSIA

Sports facilities in Malaysia have improved rapidly over the past years especially after the country hosted the 16th Commonwealth Games in 1998. The 16th Commonwealth Games was the first ever held in Asia and the last of the twentieth century. It was also the biggest sporting event Malaysia has ever hosted. The Games had necessitated the construction of the National Sports Complex in Bukit Jalil, Kuala Lumpur to cater to a wide variety of sporting events at a cost of USD200 million. The first big world class stadium in Malaysia, before the completion of the Bukit Jalil National Sports Complex, the Shah Alam Stadium was officially opened in 1994. However, upon successful bidding to host the 16th Commonwealth Games, Malaysia felt that there was a need to have another bigger sports complex which resulted in the construction of the National Sports Complex in Bukit Jalil and Bukit Kiara. This word class sports complex completed three month ahead of schedule. If not because of the Event, it is least likely that Malaysia would have such a facility. Silk (2002) meanwhile stated that Malaysia had spent a total of RM561 million (£94 million) on stadia and infrastructure for the 1998 Commonwealth Games.

Sports Facilities in Malaysia are provided based on the strategy to have both High Performance Sports and Mass Sports for all strata of the community. Mass Sport is a relatively recent phenomenon in the country and the priority of the Ministry of Youth and Sports recently has been to provide facilities for mass sports (National Sports Policy, 2007) including Kompleks Belia Dan Sukan Negara (National Youth and Sports Complex), Kompleks Rakan Muda (Youth Friendly Complex) in all States and Pusat Belia Antarabangsa (International Youth Centre). Majority of these facilities are under the Ninth Malaysia Plan (2006-2010) and they are quite new. Following this, the first sports school in Malaysia was established in 1996. Now there are only two sports schools available in the country. Sport in Malaysia is only considered as an industry in the last ten years (Aminuddin and Parilah, 2008). In Malaysia there is currently tremendous interest in sport. However, such improvements are inadequate compared to the overall development of sports at international level (National Sports Policy, 2007). This is while sport is getting more and more influential and it will continue to grow in importance as the world develops into global village, sharing the English language, technology, and sports (Majumdar and Mangan, 2005).

The government's role on sports has been confined to those carried out by the Ministry of Youth and Sports, the National Sports Council and Malaysian School Sports Council through their machinery at federal, state and district levels. The budget allocation for sports development, under the Ninth Malaysian plan, which is more than double that of the previous allocation, and of the total, 48.3 percent (RM 299.9 million) is dedicated to the construction of multipurpose sports complex. In addition, there are various plans for sports which endorse the government's seriousness and commitment's towards the development of sports and a wave of sports investment in Malaysia (Malaysian Sports industry, 2008).

DEVELOPMENT CONSIDERATION

Most of the literature on sports facilities come from the North American experiences as their professional sports facilities are very popular. However, the sports facility construction boom that hit the North American in the 1990s started to spread internationally (Fried, 2005) which lead to a lot of researches on sports facilities. In addition, there is a growing body of research addresses the impacts of large events on local communities however hosting events are as an inducement to built new sports facilities.

At a very basic level, the impacts of sports facilities are categorized as economic impacts and non-economic impacts (Chapin, 2002a). However, majority of researches on the impacts of sports facilities have also proceeded along two very different paths, one strictly economic and the other with an eye towards non-economic impacts. On the other hand, there are some researches explicitly examine the ability of sports facilities as urban change in different case studies. These studies consider different indicators for urban development to determine whether or not this has occurred. Through the reviewing the current literature it is obtained that the impacts of sports facilities and the ability to affect urban surrounding areas depend on several considerations. Location, context, culture and usage are directly affected to achieve sustainability in the sports facilities development.

Location

In the earlier trend sports facilities were located in urban dense neighbourhood, with an intentional high degree of accessibility to their working class and middle class fan base (Chapin, 2000). As cities decentralised, so did sports facilities. John and Sheared (1997) and Vickery (2007) discussed a major trend of the sports stadia construction in 1960s and 1970s was the building of large stadia on out-of-town locations where crowds, whether well or badly behaved, would create fewer disturbances to the everyday lives of people not attending events. Such locations would also reduce land costs and increase ease of access by private car. However, the next significant step in the development of the stadium occurred in 1989 with the opening of the Toronto Skydome in Ontario, Canada. The public authorities in Toronto had recognised the problems of out-of-town sites and decided to take a brave step by building their new stadium in the very centre of their lakeside city. Within the past twenty years it seems a massive return of sports stadia to the city central. Recent wave of sports facilities construction have been marked by a migration of such facilities back to the urban core. These shifting the location of sports facilities into the cities provide the new role as catalytic buildings and for spur development.

Context

Sports facilities merely are not enough for urban generation. The Visual and physical connections of sports facilities to their urban environments are key because they begin to establish a linkage between the prospects of the stadium or arena and the land around it. Cities have also begun to approach redevelopment at a geographic level rather than the individual project site (Chapin, 2002b). Research indicates that district-level planning with an expressed goal of catalyzing district development is important to realizing development outcome (Baade, 1996). The most important way to spur surrounding development is by generating coming and going: drawing people through the urban environment into the facility and later discharging them back into the environment, creating opportunities in both occasions for the visitors to patronize other buildings.

However, many scholarly studies conclude that sports facilities have not significant positive economic impacts (Baade, 1996; Chapin, 2002; Coates and Humphreys, 1999; Richards, 2005; Siegfried and Zimbalist, 2000). Chema (1996) in his article to respond Baade argued that context is the key and the value as catalyst for economic development depends on where they are located and how they are integrated into a metropolitan area's growth strategy. In 2005 Santo mentioned although Siegfried and Zimbalist declared the case closed, but this is a dangerous generalization that ignores the importance of context which is very important. He concludes a facility's ability to impact its local economy is tied to its context. His finding reports new evidence, derived from recasting the landmark study of Baade and Dye with current data, which contradicts their conclusion. It indicated that context matters.

Therefore, district-level planning has emerged as an important element in linking redevelopment to new sports facilities. The identification of downtown activity nodes and the formulation of a strategy to connect these nodes are central elements to this new approach. Sports facilities can lead to urban generation if they consider in larger development strategy. In order to overcome the isolation the sports facility development needs to be integrated into a local regeneration strategy to enhance the contribution of the sports facility to local community (Thornley, 2002).

Culture

As mentioned, most of the literature on sports facilities come from the North American experiences as their professional sports facilities are very popular. However, the culture of sports is different there. Sport has become a defining part of life and culture in North America. There is a profound connection between sports and numerous parts of life: language, holiday celebrations, national, regional, city and school identities, school social life, etc. They build new stadiums only for hosting favorite teams in their cities (Rosentraub, 1996). City officials have become enamored with ideas of constructing the newest and most state-of-the-art stadiums (Richards, 2005).

On the other hand, the culture of sport in countries such as Malaysia is different. During informal interviews through preliminary data gathering it obtains that sports facilities in Malaysia are underutilised and people do not use them. However, they are not economic oriented and the policy of government is to serving people and they are tax-exempted. Although emphasis in the Ninth Malaysia Plan (2006-2010) is placed on creating a sports culture among Malaysians to promote a healthy lifestyle as well as achieve excellence and recognition in sports at the national and international levels.

In America sports facilities have been as staple of the urban redevelopment toolkit and they will continue to serve as major urban redevelopment tools. Undoubtedly the impacts and ability of sports facilities in Malaysia is different. To study in different geographic places it is important to consider the culture of sports among people however it might have direct relationship with facilities impacts.

Usage

Another important consideration is related to sports facility usage the years after its construction. However, the sustainability of impacts is dependent upon future usage. Sports facilities are provide physical facilities but this hardware without software which is program is not able to have affects. Ken Perry assumes that the benefits accrue through attendance, and therefore measuring the change in attendance can in some way quantify these benefits.

SUSTAINABLE DEVELOPMENT

Sustainable development refers to maintaining development over time (Elliott, 1999). In recent years, sustainability has assumed increasingly importance. It is more important for sports facilities due to requirement of huge money for construction, ancillary needs and constant maintenance costs. However, there are sports facilities that have been built for world class sporting events that struggle to produce sufficient revenue to sustain annual operating costs after the event. In addition, there are examples to provide contemporary facilities for events such as Atlanta’s approach during 1996 Olympic Games. The sustainability of the impacts and longer-term effects are largely dependent upon future usage and the ability to affect the local community (Davies, 2005). This is also helps the event to avoid labeled 'the disposable Games'. This term was used by Rutheiser (1996) for Atlanta's approach during 1996 Olympic Games. The benefits of sports facilities development accrue through attendance, and therefore measuring the change in attendance can in some way quantify these benefits (Perry, 2001). On the other hand, sustainable development seems to be more efficient especially for developing countries which are faced with a strong economic, social, and environmental need.

It is a new approach to the planning and design which is expected to guide the physical planning system focusing on the concept of sustainable development. Physical land use planning has a major role in achieving sustainable development (Dasimah, 2002). As mentioned earlier, recent shifting the location of sports facilities into the city area, at the same time, changes in the nature of planning and urban development in a series of large-scale urban redevelopment projects, has provided sports facilities new role for spur development. in addition, it depends how to connect to surrounding area. Sports facilities can lead to urban generation if they consider in larger development strategy. This trend can be used for hosting sports events. Further, Legacy programme which was an innovative attempt adopted in conjunction with the 2002 Commonwealth Games to ensure that the Games left a lasting legacy for Manchester and the North West of England (Smith and Fox, 2007). Gratton *et al.* (2005) claimed that it represents the first time in Britain an ambitious legacy programme was designed around a major sport event. It was for the period 1999-2004. The mixture of projects linked to the Games was a key strength of the legacy programme. It encouraged a greater range of benefits than would otherwise have been possible. Events seem to leave a more positive physical legacy when they are embedded within wider regeneration strategies. Barcelona provides another example, as it had talked for over 25 years about many of the changes now associated with the 1992 Olympic Games. Principally, this event provided an important incentive and deadline to complete long-held visions to develop road and transport infrastructure, housing, office and commercial developments; and hotel facilities. More was spent on each of these four types of development than on new event venues. The Olympic Games left a comprehensive physical legacy that provided the basis for Barcelona's subsequent economic regeneration. Urban development that includes an event encourages urban development rather than using an event (Carriere and Demaziere, 2002).

However, new generation of sports facilities are along with development of city life. They complement a mix of residential, commercial, retail, dining, and entertainment spaces as real life center and a 365 days using. Further, by focusing on non-game elements that allow the flexible facility to work on different ways all the years and so to develop the revenues in the sports facility and around.

CONCLUSION

The research undertaken for this study is part of an on-going doctoral study that aims to explore the existing sports facilities in Malaysia and to examine the physical, economic and social impacts of the case study. However, there is a recent interest in sports facilities development in Malaysia, at the same time, current sports facilities construction boom universally. Further, recent development has taken in consideration the most important issues of all the environment and actors of the facilities, from fans, to players, from communities to investors. They have also considered as an important role in urban development.

Requirement of huge money for construction, ancillary needs and constant maintenance cost, as well as, increase in the number of sports facilities and enhance the role of sports shows the need to consider on sustainable development for sports facilities. However in developing countries which experiencing a crisis finance, facing with a strong economic, social and environmental needs, sustainable development has assumed increasingly importance.

Sports facilities developments have a wide range of positive and negative impacts on their surrounding areas and wider cities. The ability of sport facilities and longer term benefits depends on several consideration including location, context, culture and usage. Further research will provide information on the physical, economic and social impacts of the case study on urban development in Malaysian context.

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DEVELOPMENT OF A METHODOLOGY TO GENERATE QUALITY KNOWLEDGE FROM STAKEHOLDERS TO DESIGN AN ENERGY AND COST EFFICIENT PRIMARY SCHOOL

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Carbon reduction has become a global aim and goals have been set by the UK government to reduce carbon emissions by 60% by 2050. According to the DEFRA, the construction industry is one of the major sources of the CO2 emissions that are causing climate change. Encouraging the construction of energy efficient buildings is one of the methods by which the UK government thinks its ambitious carbon reduction target can be met. Strategic selection of sustainable materials and building design prior to the building construction is crucial to increasing building life cycle energy performance. However, stakeholders involved in early design process often have conflicting priorities for both building design and construction materials and this makes decision making a complex task. This research contributes to the simplification of this task by developing an environmentally focused decision support system in the form of an Environmental Assessment Trade-off Tool (EATT) which supports the development of the ideal building design and materials combination which meets stakeholders' requirements. Analytical Hierarchy Process (AHP) is the trade-off approach used within EATT decision support system. This paper gives an overview of functions and features of AHP, illustrates how AHP is incorporated within the EATT decision support system and highlights how this system can be used to inform the design of low carbon energy efficient buildings.

Keywords: energy efficiency, trade-off, AHP, stakeholders' participation

Introduction

Carbon reduction is a global aim. The construction industry is one of the major sources of CO2 emissions. Forecasting the energy performance of a building during the early phases of its design has been suggested as a method of informing the development of low carbon buildings (InPro 2007, Loh 2009a). However, very little consideration of the environmental impact of proposed buildings occurs during the early design phase (Ding 2008). This is partly because building assessments are most often carried out after designs are finalised (Soebarto and Williamson 2001). Time and cost are the main constraints which restrict consideration of the environmental impact of a proposed building during early design planning (Crawley and Acho 1999). This is problematic as extra costs and time is incurred when changing a building's design during the later stages of its development. Therefore, it is important for the construction industry to assess and rehearse the potential environmental

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impacts of a building during the early design process, if cost effective energy efficient buildings are to be developed.

Recently revised, UK building legislation demands energy performance documentation as part of the building planning permission process. Clients also request contractors to demonstrate the building performance at the planning process (BSRIA 2009). This is putting pressure on contractors/developers consider environmental issues at the outset of their project development agenda. This legal mechanism has clearly increased developers awareness of their responsibilities with regard to sustainable building design. It is common practice for developers to appoint a sustainable building expert during the design process. Ecologists and environmentalists can also be involved in large scale projects. However, multi-stakeholder involvement makes the decision making process more complex. This is because those involved in the design of a building often have conflicting priorities. Hence, a trade-off tool is necessary to assist multi-stakeholder decision making.

The research presented in this paper contributes to the simplification of multi stakeholder decision making by developing an environmentally focused decision support system in the form of an Environmental Assessment Trade-off Tool (EATT). This tool allows stakeholders to assess building energy performance and the effectiveness of different design options during the early design stage. The main functions of the EATT are materials and project assessment.

1) Material assessment- EATT analyses the cost benefit of material options in order to generate the best material combination that meets stakeholders' requirements.
2) Project assessment – EATT analyses and compares the life cycle cost, capital cost and energy performance of different materials and building layouts.

Analytical Hierarchy Process (AHP) is the trade-off approach used within the EATT decision support system. AHP was selected because it supports trade-offs with and without tangible values. For example this approach enables aesthetic issues as well as environmental impacts to be considered. This feature is important as decision making in reality engages with solid, verbal and subjective elements.

Decision making using AHP

Analytical Hierarchy Process (AHP) is based on priority theory. The elements of a model are broken down into a hierarchy tree and a numerical value scaling from 1-9 is used to define the importance of each task. This method is usually applied in cases with limited criteria.

The benefit of AHP is that, it models complex preferences based on specific criteria at the outset of the project enabling a simplification of the decision making process. Linkov et al (2006) suggest that "*AHP assumes that humans are more capable of making relative rather than absolute judgments, but at the same time it allows room for the application of heuristic human reasoning and expertise*."

The successful application of AHP has been reported from a wide range of research sectors for different purposes (Wong and Li 2008, Ho 2008). However, this might not be the case for construction industry. This is because cost control is always the target for construction practitioners and this makes decision makers bias on cost reduction. This also means that a cheapest alternative is predictably shown as the best alternative.

Another AHP application called benefit/cost AHP method will solve such issues. This approach will be discussed in the next section.

Integration of cost benefit analysis with AHP

Cost benefit analysis is a tool commonly used in project evaluation which is used to compare the financial cost of different alternatives. Saaty has integrated cost benefit analysis with AHP (Saaty 1980, 1995). The only difference is that conventional cost benefit analysis uses financial comparisons alone while the benefit/cost AHP analysis incorporates the AHP preference system to draw comparisons. The advantage of the benefit/cost AHP method is its flexibility when comparing non-currency units (Wedley et al 2001).

Saaty's benefits, costs, opportunities and risks method (Saaty and Cho 2001) and benefit/cost procedure (Saaty 1994) being implemented for different problems was suggested to be the most adopted and best AHP approach to support the decision making process that consists of benefit and cost elements. However, benefit and cost hierarchy was built separately in Saaty's approach and users cannot adjust the benefit/cost ratio (figure 1). This might cause result inconsistency.

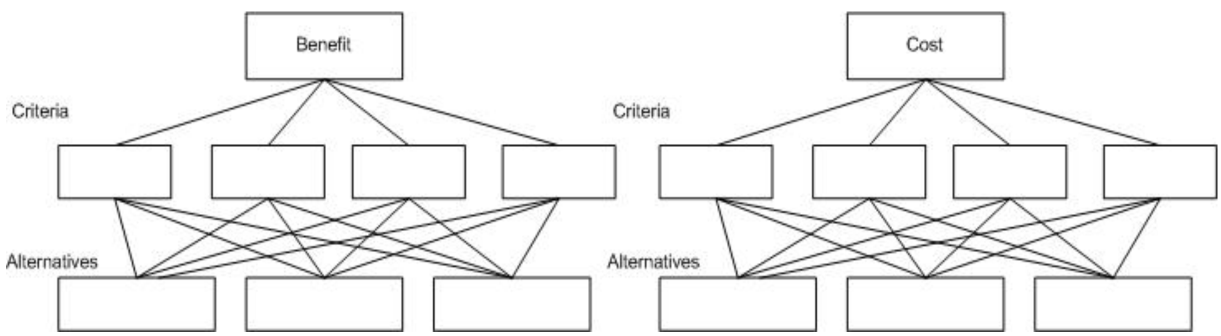

Figure 1: Saaty's benefit/cost AHP hierarchy

Wedley et al (2001) tackled this problem by incorporating the magnitude adjustment process for the AHP benefit/cost ratio (figure 2). The idea is to combine the separate benefit and cost hierarchy (that propose by Saaty) into one hierarchy. This approach supports benefit/cost ratio adjustment without losing the original feature of Saaty's AHP—subjective decision.

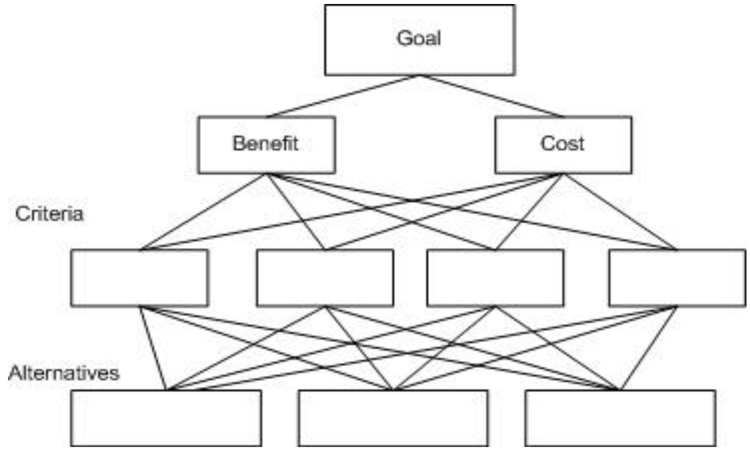

Figure 2: Structure for benefit/cost AHP with magnitude adjustment

In summary, the benefit/cost AHP incorporating magnitude adjustment process was considered as the ideal approach that fits best with the early design process and these approaches will be adopted in this research. Another reason to select benefit/cost AHP approach is because it prevents bias on cost and allows fairer trade-off process.

Implementing benefit/cost AHP as a trade-off method for Environmental Assessment Trade-off Tool (EATT)

As a conclusion of the review, AHP cost benefit analysis is suitable for the case of this research and therefore it has been use to develop a decision support system called Environmental Assessment Trade-off Tool (EATT). This tool was developed using the MsExcel and is being used to assist group decision making for building material selection and procurement in different stages (Loh et al 2009b). The implementation of EATT is articulated in figure 3.

It is important to express that the solution provided by EATT is not necessarily the most sustainable design approach or the cheapest solution. What it provides is a solution that meets most of stakeholders' requirements (Ie. Certain criteria will be compromised; decision making depends on the stakeholders' priority assigned to the criteria).

Benefit of EATT

The following are the benefits expected from the application of EATT:

- The main point of difference from off-the-shelf assessment tools is that these tools only trade-off numerical values whereas EATT supports trade-off with and without tangible values, such as a clients favour over a particular building design, publicity potential of the building design, client's priority distribution for long term and short term cost, use, etc. This feature is important as decision making in reality engages with solid, verbal and subjective elements.

- The tool to be developed allows clients to set a detailed priority distribution for both long term issues and short term costs. For instance, clients can decide how much they are prepared to spend on different variables of construction cost (initial cost, life cycle cost). This feature allows clients to take control of their budgets. Additionally, the cost transparency inherent in the EATT processes can reduce bias associated with construction cost during the decision making process.

- The revised UK planning legislation and climate change legislation forcing all developers to submit supporting documents that demonstrate the building performance during application for planning permission. The BREEAM certificate is one of those supporting document. Generally, contractors tend to spend more cost at the near end of the construction phase in order to obtain a BREEAM credits target used to signify building performance. Trade-off during the early design process using EATT, being created based on the BREEAM rating system and the BRE green guide specification, will give a better chance for the proposed building to attain a high BREEAM rating with minimum cost and time.

Process flowchart to select the best material-layout design combination

This section will illustrate the main procedures to achieve sustainable building design with the assistance of EATT (figure 3).

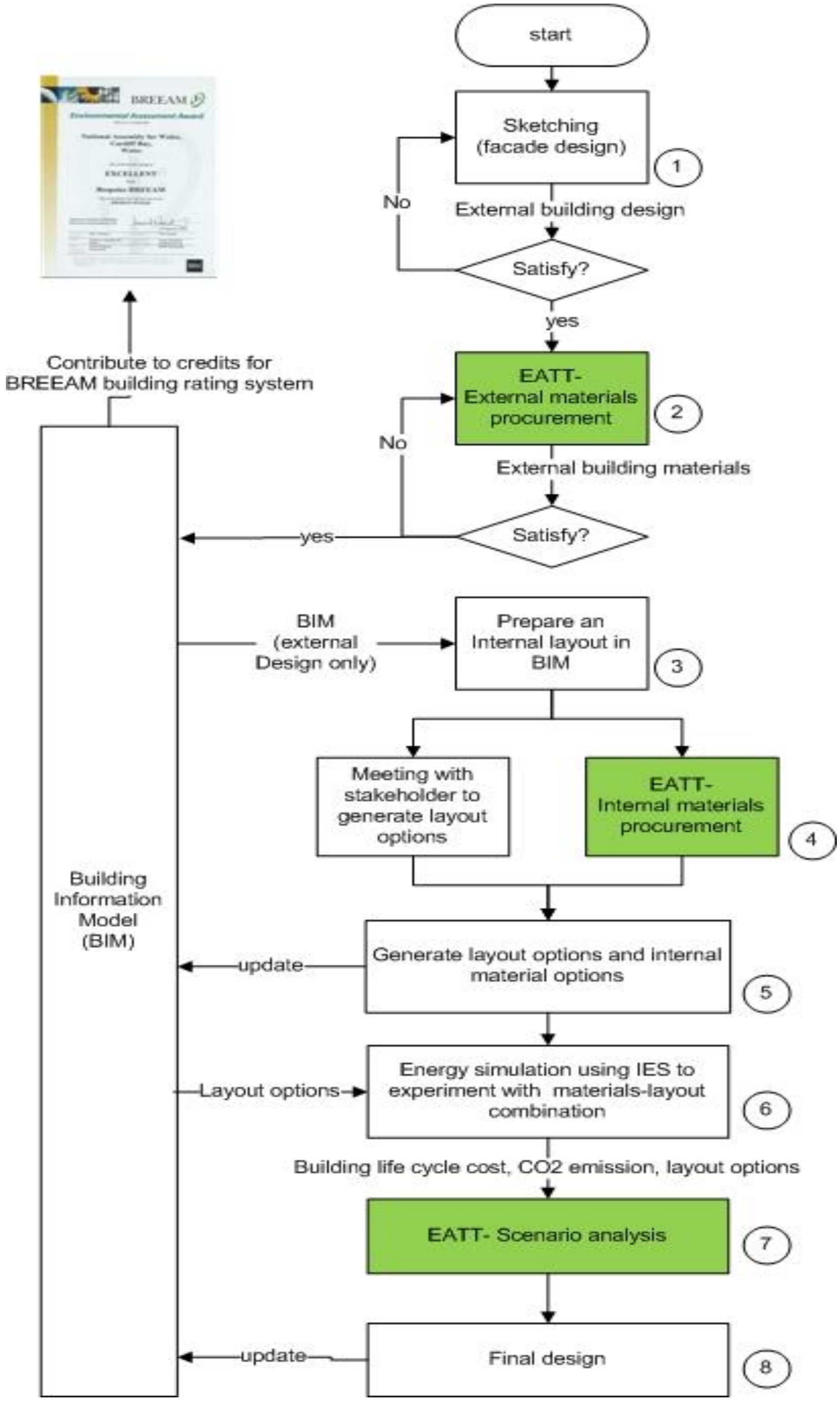

Figure 3: Process flow chart to select the best material-layout combination

Below is the explanation of the process flow chart mapped with the numbering in the figure 3:

1. A facade design and main structure will be sketched according to the clients' requirements. At this stage no simulation will be carried out as there are very little data for simulation. Architects often, merely conceptualise the external building design based on their experiences.

2. The EATT employs the AHP method to assist external materials procurement. The idea is to select sustainable materials that meet the clients/architects requirements. Roofing, external wall and external windows will be selected individually using a trade off approach. The best alternative for each building element will be used to finalise the external materials of the proposed building. If the design team is satisfied with the result, the BIM model (building skeleton only) will be developed in Revit or step 2 will be repeated until the external design/materials is finalised.
   It is important to express here that the trade-off criteria are based on the green guide specification[1], which is used in the BREEAM pre-assessment. Table 1 show the criteria and alternatives for external material selection using EATT.

3. The next phase of the process involves modelling different internal layouts for the building with a Building Information Modelling tool.

4. Once the internal layout options have been designed, a meeting will be arranged and the proposal will be given to stakeholders. New ideas input from stakeholders means that a new internal layout is very likely to be created at this stage.

   At the same time, a material trade-off will be conducted in the same way as in step two but this time considering internal building materials: These will include internal walls, ceiling, doors and internal windows.

   As an outcome of the meeting with stakeholders, a few sets of material options and layouts will be generated. This information will be used for energy simulation in the next stage.

5. An energy simulation software called IES is used to conduct both energy assessments and life cycle cost assessments for the alternative building layouts developed. These assessments will test the design approach by using the materials options generated from the previous step.

6. At this stage, architects are able to view the what-if scenario for different design/materials combinations. However, it is also more difficult for architects to finalise the best building design as there are further detail variables (building life cycle cost, construction cost, energy performance, etc) that need to be taking into consideration.

[1] Green Guide Specification is a material rating system that developed by Building Research Establishment. It consists of environmental profile of main stream construction materials in UK

7. EATT will be used to select the final material-building design combination. Building alternatives will be traded-off using criteria including the client requirements upon the life cycle cost of the building, construction cost, energy performance and design compatibility with the BREEAM design requirement.

   Finally the best building design will be selected. As the criteria are referred to the BREEAM and green guide, the final model that complies with most of these criteria is the most likely to achieve a high BREEAM rating.

Table 1: Criteria and alternatives for external material selection

Source of information	Criteria	Alternatives
Green Guide	Material rating, climate change, fossil fuel depletion, human toxicity to air and water, ecotoxicity, typical replacement interval, recyclability	Roofing, external walls, external windows
Subjective	Aesthetic, uniqueness	
BREEAM	Match with existing	
Green Guide	Material cost, Material LCC	

Case study

A case study is currently undertaken by using a primary school project (figure 4) provided by Durham County Council. This case study is still ongoing by the date of writing this paper. The primary school project data has been used to carry out the EATT prototype to test the material selection process.

Figure 4: Front view of the primary school

To test the material procurement process, three researchers with construction background has been invited for role play. Each of them has been assigned as a consultant, an architect and a client. Design brief have been explained to them.

The case test started with altering the internal layout in group. An alternative option was produced in the first 40 minutes. This design alternative along with the proposed layout design being used to run energy simulation with the material combinations. Figure 5 is the proposed layout and figure 6 is the alternative design generated in the stakeholders' meeting. Major changes were made at the south wing (where the classroom located). The alternative design has a slightly bigger footprint at the south wing and classroom is more spatial.

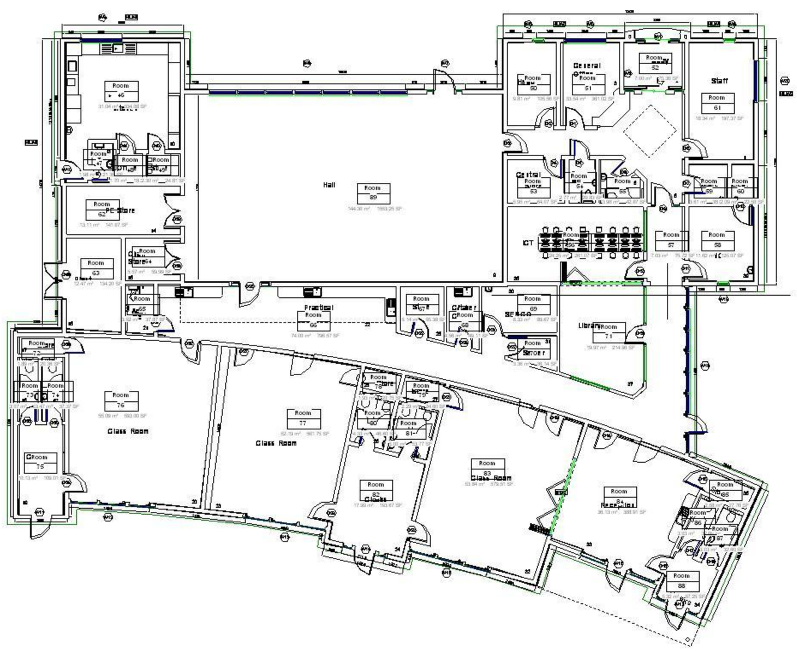

Figure 5: First design proposed by the architect

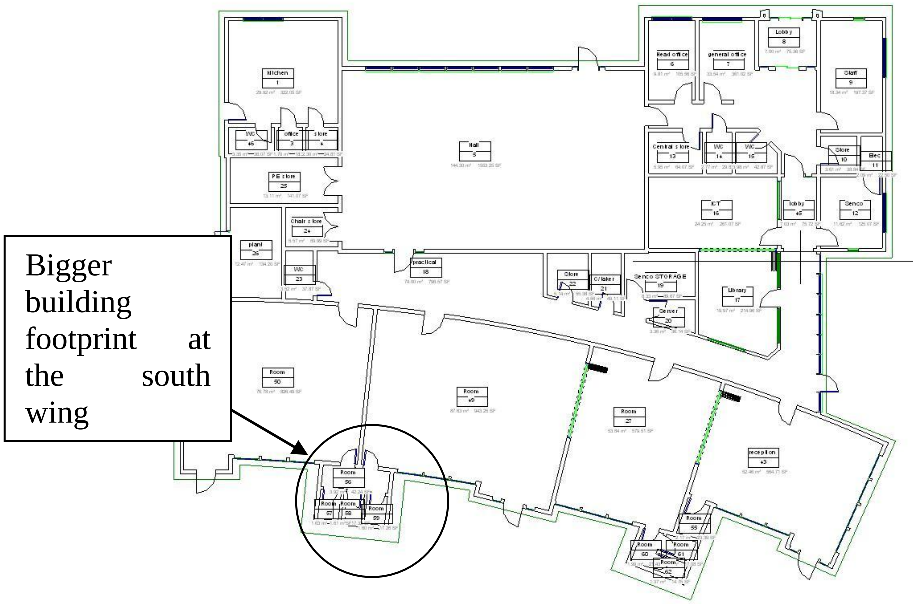

Figure 6: Alternative design generated in the stakeholders' meeting

Next step is where each stakeholder selected their own preference materials for the building by referring to the material's data table of the green guide specification. Two to three sets of material was selected for every material category.

After materials were selected, stakeholders are required to set the standard criteria priority for the project. As a result of material trade-off, the best, second and third best material combination consisting of materials' preference from three stakeholders was generated (Table 2). As there is multi stakeholder involvement, the best material combination is the accumulated result from stakeholders.

Table 2: Accumulation of material combination based on the criteria priority

	Best material combination	2nd material combination	3rd material combination
Roofing	Consultant	Architect	client
External wall	Consultant	Client	architect
External window	Consultant	Architect	client
Intenal wall	Client	Architect	consultant
Internal window	Consultant	Client	architect
Ceiling	Client	Architect	client
Door	consultant/architect	consultant/architect	client

The outputs from the material combination stage are then input into the energy simulation software to simulate the energy performance and the life cycle cost performance of different material-design combinations. Table 3 is the simulation result of the material-design alternative. Heating cooling system variables were not included in the simulation.

Experiments with material-layout-heating cooling systems will be in the next stage of the case study.

Another material-layout simulation was carried out based on the existing building design. The idea is to use this simulation result to benchmark and compare with the proposed material-design alternatives. See table 3 for the simulation result of the existing and proposed building. The existing building has the cheapest capital cost. However, its material life cycle cost was the third highest compared with other alternative building designs. By investing the extra capital cost of £51,828, the building life cycle cost would save £486,285 or 22% over 60 years.

Table 3: Simulation result of design alternative and existing building

Alt	CO2 emission	Energy consumption	Capital cost (materials)	Energy life cycle cost	Material life cycle cost	Total LCC(60)
	kgCO2/m2	MWh	£	£	£	£
1	39289.3	128.588	332,454	110,869	428,145	871,468
2	38782.2	125.974	294,456	108,643	708, 042	1,111,141
3	37969.8	121.787	294,714	105,030	985,195	1,384,938
4	35966.9	121.202	329,671	104,514	412,792	846,976
5	35551.0	116.997	284,157	100,884	719,065	1,107,236
6	34805.1	113.152	284,889	97,577	983,557	1,366,024
**	35300.7	115.707	277,843	99,787	955,631	1,333,261

**Existing building data to be used as benchmark data

The conclusion of this study is that material selection should be taken into account as it has huge impact on the building operation cost. EATT assists the material selection from multi-stakeholders by considering the cost and benefit of every material.

Summary

Careful selection of materials and building design before the construction of the building has been suggested as a critical step to reduce the building life cycle energy performance. Usually different stakeholders will be appointed to assist the achievement of sustainable building design. The challenge for multi-stakeholders involvement in decision making is that, everyone has their own perspective and it is impossible to include every stakeholder's preference in a project. Therefore, some options need to be compromised.

The solution proposed in this research was to develop a tool to support the decision making process. This tool known as EATT where it trade-offs subjective and objective views of stakeholders and it provides a solution (in this case is the material-layout combination) that meets everyone's requirements. The AHP approach was selected to develop this decision support tool. A case study has been reported in this paper and the findings indicate that careful material selection using EATT could reduce the building life cycle cost significantly. Further research will be continued to explore the possibility of using the proposed decision support tool to support existing building refurbishment.

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