Ph.D. RESEARCH WORKSHOP
on
TECHNOLOGY AND INNOVATION IN CONSTRUCTION

Held at
Department of Civil, Mining and Environmental Engineering, Luleå University of Technology
Porsön, Luleå

29 September 2010

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0930hrs	Connecting research and practice on technology and innovation in construction	**Professor Ove Lagerqvist** *ProDevelopment AB*
1000hrs	Design tools for industrialised construction: changing the practice	**Tamás Rácz** *Luleå University of Technology*
1030hrs	Clients as drivers of innovation: lessons from industrialised construction in Sweden	**Susanne Engström and Erika Levander** *Luleå University of Technology*
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1115hrs	Knowledge generation and business model changes: The case of Green Construction	**Shahin Mokhlesian** *Chalmers University of Technology*
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1400hrs	*Close and travel to Gammelstad Church Town (till around 1800hrs)*	

EDITORIAL: TECHNOLOGY AND INNOVATION IN CONSTRUCTION

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CONTEXT

Over the last thirty years, there has been a great deal of interest in the study of innovation within the context of the construction industry. Early scholars have been concerned with the measurement of innovation in the sector with particular emphasis on the structural characteristics that encourages innovative practices and the adoption of innovation (see e.g. Hartmann, 2006; Hartmann *et al.*, 2008). Consequently, numerous studies have emerged in the past comparing cross-national and cross-sectoral perspectives (see e.g. Gann and Senker, 1993; Gann, 1996; Manseau and Shields, 2005), as interest grew in determining the factors that can enhance innovative behaviour of construction companies (see e.g. Tatum, 1986; Pries and Janszen, 1994; DTI, 2003; BERR, 2008; Barrett *et al.*, 2008).

More recently, however, scholars have taken a critical turn to examining technology development and innovation in construction. Green and May (2003), for instance, questioned the orthodoxy of "re-engineering" construction and suggested that it is essential to consider the local-embedded nature of construction work. Others have also examined socio-technical aspects of innovation, tracing the impacts of technological advancement on working practices and the livelihoods of those utilising the built environment (see e.g. Harty, 2005). More recently, there is a growing interest in developing a more nuanced explanation of innovation in the construction industry, by challenging conventional norms in the recognition of what constitutes innovation (see NESTA, 2007).

Therefore, the attention of research into technology and innovation in construction has shifted away from macro-level analysis to emphasise the dynamics of development in these areas and the implications on firm-level, project-level, and individual-level practices. Following the call for participation in this workshop, potential research questions were framed to form potentially useful areas for discussion, including:

- What are the opportunities and challenges associated with technology development and innovation management in construction, especially during the current financial climate? And how are these shaping working practices in the industry, in the present and the future?
- Technological advancement and innovation have often been seen as positive concepts. However, what are the unintended consequences of technological advancement and innovation in construction? And how do we conceptualise the limits of growth in this area?

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- What methodological problems arise when studying technology and innovation in construction? How can the construction management research community contribute to methodological developments in this field of study?

THE PAPERS

As a result of the call for participation, four papers were accepted. These deal with a range of issues, including how the dynamics of technological development might shape the roles of stakeholders in the industry, clients' response to innovative techniques, how new concepts in the industry are perceived by a plural landscape of stakeholders, and how collaboration can be encouraged among small to medium sized enterprises (SMEs) operating in the sector.

In the first paper, Rácz reports on preliminary findings of research that seeks to develop new design tools to capture the dynamism of industrialised construction in Sweden. Rácz reflects on the challenges confronted in the introduction of new production methods in terms of stakeholder perceptions of such methods and associated information requirements. In developing appropriate design tools, he also discusses the tension between the desire to standardise designs on the one hand, and the ability for such information models to cope with flexibility and adaptability. Furthermore, Rácz notes that roles of stakeholders evolve with technological change, and that this needs to be accounted for in any tool development.

One of the most critical stakeholder in promoting technological development and innovation in construction is the client. Engström and Levander stress the importance of equipping clients with adequate information, so that decisions are made to appropriate innovative solutions. In the context of industrialised construction, they argue for the development of more sophisticated information processing capability to encourage more early adopters of innovation in construction.

Yet, information is not unproblematic. Mokhlesian presents a review of the "Green Building" agenda, outlining the diversity of value propositions in the literature. This, it is argued, presents great difficulties for developing a general business model that can be adopted by the industry to effectivise the green agenda. As Mokhlesian notes, "it is difficult for managers to search directly for new valuable knowledge; instead they need to focus on valuable problems that when solved lead to new valuable knowledge. The complexity of the valuable problem determines the organization of search for new knowledge, i.e. the problem complexity determines at least to some extent the set up of the business model."

Finally, Erikshammar and Lassinantti presents ongoing work to develop a specific collaborative business model for the Swedish housebuilding industry. The intention of this research is to integrate the SMEs operating in the sector to participate effectively in the new product development process.

From the papers, it is clear that technological development and innovation in construction are not straightforward concepts that can be reduced to the determination of structural characteristics at the macro-level, or in terms of cause-and-effect that is often promulgated by early research in construction management. Instead, practices at the firm, project and individual levels are fertile grounds for understanding how technology and innovation plays out in reality. Researchers have often remained sanguine about the promises of technological advancement and adoption of innovation, thereby neglecting the paradoxes, tensions and contradictions that frequently arise in the theorising and enactment of such concepts. It is hoped that the papers contained in this set of workshop proceedings would generate a fruitful discussion on these under-explored areas.

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DESIGN TOOLS FOR INDUSTRIALIZED CONSTRUCTIONS: CHANGING THE PRACTICE

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Industrialized construction processes promise higher efficiency but require different approaches. The industrialization not only alters the performance of the buildings but also alters the role, communication and activities of the stakeholders in strong correlation with changes in construction processes. Changes in processes set new requirements towards software tools of the construction process and at the same time the evolution of software tools provide new possibilities to consider. The development of building systems – systems for managing industrialized constructions – require the existence of customized software solutions instead or in parallel to more generic ones supporting the traditional processes. Processes supported with customized software tools could not only be quicker and more efficient but better in quality, however require different approaches in development, usage and maintenance of processes. The author is participating in the research project of investigating the application of software tools supporting design for industrialized construction processes. This paper intends to draw summary on requirements and implications of applying design tools on industrialized processes. We will discuss the evolution of design tools, requirements towards tools and organizations, role changes and information management. The paper will also discuss the difficulties we face during the introduction of the new breed of design tools required for industrialized construction processes and some difficulties of the research activities. The paper is finished with summary on planed and possible future works in the area.

Keywords: industrialized construction, building systems, development, design tools

INTRODUCTION

In the long lasting quest of improving the productivity, quality and predictability of the construction processes the adaptation of manufacturing industries' mass customisation techniques, the formation of industrialized construction is a very promising concept (Lessing 2006). The concept of industrialized construction is moving away from the traditional, one of a kind 'engineering to order' approach and introducing several new ways of forming the building product. Based on the so called customer orders decoupling point of Hansen (2003) these new ways include the practice of 'modify to order', 'configure to order' and 'select variant' ones (see Figure 1.).

From the 'engineering to order' practice towards the 'select variant' approach the new solutions require increasing level of preparation before starting the actual construction projects for building instances. We could call building instance related activities as realization. The preparation includes the selection of product range to deal with, designing and manufacturing components, defining procedures. We could call these activities product development. The increasing level of development results in

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decreasing level of flexibility, the space for customization is increasingly confined in the realization stage; custom solutions require product development before the realization could begin. In other hand the realization stage require less work.

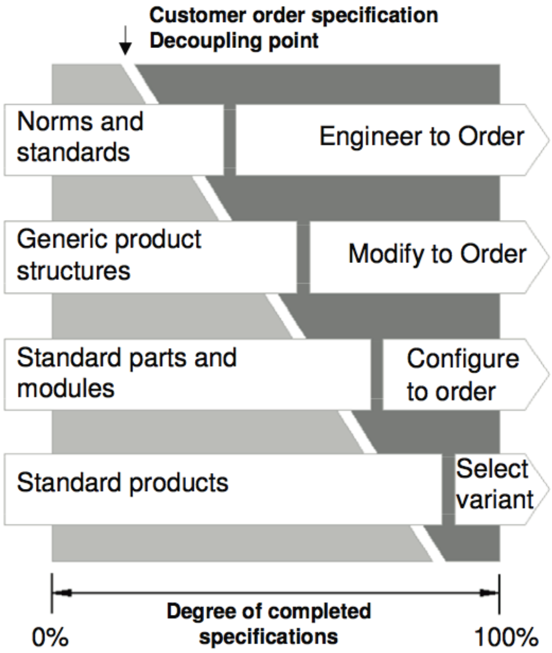

Figure 1: Customer orders decoupling point; from Jensen (2010)

The changing level of pre-production and flexibility results in the change of practice. The client communication for example shifts from the tailoring to needs kind of activity towards selecting the closest optimal from among the available solutions. Also the design activity becoming less prominent in the realization phase but it is moving into the development phase where the intent is not to design one complete item but components and product families that could be used for constructing complete items, building instances. The solutions supporting the new kind of construction processes also change. Following Jensen (2010) we call the collection of supporting solutions building systems. Building systems consist of process and technical platforms that help in the phases from capturing requirements until the delivery phase. These building systems typically need their own breed of software solutions that can support the new kind of approaches.

In our research project we investigate the development and use of building systems where the first author's task is to investigate software tool application for such systems. The goal is to collect information on the actual situation (problems and requests expressed), on the development of tools (requirements, solutions, difficulties, consequences) and as far as possible on the usage of the system. Recent papers include analysis of the software development practice for construction industry today (Rácz and Olofsson 2009), development of automated energy analysis module (Rácz, Rönneblad & Olofsson 2010) and proposed application of decision making methods for building systems (Rácz and Olofsson 2010).

In the following sections we are going to identify issues identified and foreseen around creating software tools for building systems supporting industrialized construction processes. The issues are grouped into technical, organization and research related chapters.

DESIGN TOOL EVOLUTION

Industrialized construction processes do not require in fact the availability of special software solutions. However, the confined solution space nature enables the creation of simpler and more stable schema of operation for the realization stage and calls for the use of computers. The more explicitly formulated and repetitive actions of industrialized processes could be more efficient if performed by computers.

Compared to the software tools aiding the traditional construction processes the software tools of building systems could become more specialized to the actual system. Traditional software tools tend to specialize to the field of activity and the type of structure (analysis tools, design and detailing tools or tools for steel, concrete, wood structures) but those are still made to support very wide range of design solutions. In contrast the very essence of industrialized constructions is to select product range to be supported by a certain building system (Hvam, Mortensen & Riis 2007). Hence software tools used in building systems will be used only for a narrow selection of products, the solution space is smaller and at the same time the properties and attributes of the product range is predetermined to a wide extent. To make high performance tools for specific situations is easier than for broad set of solutions.

However purpose made solutions, solutions capable of handling only a narrow set of products could hinder the possibility of reuse. While generic tools could be used for new kinds of products the special solutions need adjustments. This brings the consideration of creating more generic tools that are handling not only the selected product range but also other, possible future products. The right balance of general and special solutions should be found. Other solution is to seek for modularization, which is indeed an existing and welcomed technique in today's generic tools because of software management considerations.

The creation of building systems includes the new activity of development for the selected product range (Hvam, Mortensen & Riis 2007). When the decision is that purpose made or customized software should be used in the system then the development team needs to incorporate software engineering knowledge. The construction engineer and software engineers should work in close correlation or team members themselves should have combined abilities. It is likely that the involvement of software engineers is not a one-time activity but the software engineering knowledge is to be used continuously for the lifetime of the system. During the testing, introduction and maintenance as well as during the improvements of the system the manipulation of custom-made software tools is necessary. Organizations wish to introduce industrialized solutions and building systems might need to have continuous access to software engineering staff.

The narrow field of product range and the consequent narrow scope of non-predetermined product information results in fewer possible alternatives and so more simple process and information flow for the realization phase. Also many parameters are fixed in the development phase hence less to decide and work on. The more simple processes could open up the possibilities for software algorithm creation for parts of the processes. Consequently computers instead of manpower could perform certain activities. Higher extent of design, analysis and information management could be handled without human interaction. In case of standard products (Figure 1.) probably the whole set of processes could be automated but even in case of standardised parts and modules the otherwise time and human resource intensive cross discipline operations (eg. from architect to structural engineer) could have more or less automation. Since the solution space is confined, preferred or optimal solutions could be fixed during development. The interpretation of building design and creation of discipline specific models might be simplified or automated.

The underlying information management of building systems might raise previously less dominant difficulties. The development phase of building systems produce vast amount of information on the construction from various disciplines. The information storing requirements and data formats of the various disciplines are usually different. Software tools of the disciplines have their unique data schema and file formats, as well as procedures. Building systems need to support the various information management requirements of disciplines; technology that supports all possible variations should be found. As the stored information could vary even during running projects flexible systems is anticipated without pre-defined schema of the data. The difficulty is not only to find the solution that satisfies all needs but also that generic solutions are usually less efficient than those assume certain data format.

CHANGING PRACTICE

The change in industrialized processes alters the work method of team members. It is different to design and work with a one of a kind solution than design for a whole product range and later configure the template products several times based on the available options. More work should be put into the development phase of building systems while working in the realization phase is shorter and confined. Engineers might receive this positively but architects might feel of loosing space for creative thinking (Jensen 2010). On the positive side we could mention that the less work in the realization phase means that stakeholders could investigate more alternatives during the same given period of time, especially when automation is involved, consequently having more chance of finding the optimal alternative. Or it is possible to switch between projects more quickly.

The new kind of activity of development and system maintenance should be addressed in the organizations (Hvam, Mortensen & Riis 2007). As it is mentioned above the development might include software development responsibilities too. Teams should be established for development and system maintenance tasks. Further new task is the interactions between the development and project realization teams. Requests should be delivered towards the design team and instructions towards the realization team. A further important consequence is that the client communication responsibilities are altered.

The construction industry is traditionally fragmented concerning the involved business units and organizations. Projects could have several independent players to involve, generic contractors, architects, engineering consultants, constructors, other subcontractors. Not even the tasks but the responsibilities and legal bindings are distributed across organizations. Software solutions of building systems work better when the solutions are homogenous. However the development, maintenance and improvement of a building system could be more difficult if independent decision making organizations are to participate. In Sweden the industrialized construction initiatives have came from middle sized or big companies so far (Jensen 2010) and the developing companies own the building systems exclusively. For wider base of introduction the inter-organizational barriers should be lowered. Proper technology and techniques should be chosen or developed.

Effective building systems covers the whole construction processes from conceptual phase to delivery phase and the processes form an integrated chain. The introduction of the building system affects all phases of construction and the methods used in the phases should be compatible, made to work in only a certain combination. Therefore building systems should be introduced in one piece. This could be a risky move if it is done for the whole organization. What is a less risky move is to form a team that develops the first version of building system for a narrow – but still wide enough to address client needs – product range. After development and successful test runs the rest of the organization could be involved in the new kind of practice (Hvam, Mortensen & Riis 2007).

RESEARCH ASPECTS

Building systems integrate practice and professional knowledge from various fields into one seamless system. For operating successfully it should built for the need of the disciplines involved. Because it integrates the disciplines the changing practice of professions and practice affect each other and the overall process more directly. During the alteration of discipline specific activities the conditions towards each other should be considered. For example changes in engineering designs might affect client communication activities directly through necessary input definition and it might be directly affected by changes in procurement practice. Also since for an effective system the use of computer technology is necessary information technology expertise required: understanding the requirements of software engineering becomes the essence for developing and maintaining a building system. It seems to be practical if the involved researchers have higher than usual understanding of other related fields of their professions to assess the effects of changing practice. At least to have research team members from multiple disciplines seems to be essential. The acquisition and the coordination of the various expertises could be difficult and time consuming.

For the validation of methods and for investigating the issues of introduction industrial ties interested in industrialized construction should be involved. Here as for researchers the complete set of disciplines should be available as the building systems cover the whole process chain. Likely companies with broad field of practice is the best to cooperate with instead of numerous specialized ones however the fragmented nature of the construction industry will not be represented in the research project then. Additionally to find a realistic and practical scenario where new findings can be validated could be a problem as elements of the building systems might not be operated individually and the validation and test of bigger and complete system might be risky. Likely it is necessary to find partial application scenarios, for example limited product range to support where fewer people are involved; however the product range should be wide enough to have practical value.

The author is involved in the research as an industrial PhD student, which means that he is employed in the industry part time. The findings of the studies are expected to contribute to the success of the affiliated company, practical findings are eagerly awaited, therefore support is given to a great extend for the research. However the daily situations and requirements might temporarily overweight the long-term interests of the research or influence the focus in the research. These easily result in a somewhat unstable research path where the future results could be difficult to predict for the individual. This might be negative for the sake of a sound academic thesis but since it reflects the requirements of the industry the findings might be still valuable regardless of the irregular research track. The scope of industrialized construction is quite wide so the research has numerous possible paths to choose from; a continuously changing research track could be as valuable as one that predefines many years of activity and hold on to the track. It is only difficult sometimes to harmonise the formal requirements of the academic word with the fluctuating nature of the industrial ties.

SUMMARY AND FUTURE WORK

We seen that – partially through previous publications – the required new work methods and tools of industrialized construction result in organizational changes and the emerge of previously non-existent, less dominant or separated activities like system development (Hvam, Mortensen & Riis 2007, Rácz, Rönneblad & Olofsson 2010). Client communications, design practice, project management, software tool development, use and management issues were highlighted here from among the many possible ones. Further aspects around staff responsibility, procurement, manufacturing, product development and on site construction activities would worth further investigations.

The author continues to experience in creating software modules for building systems that are able to perform various design and analysis activities, as far as possible in a less labour intensive automated manner. The ultimate goal is to investigate the information technology aspects of building system development and the application of automation. Likely the author will encounter further construction project and process flow related issues as these directly affect the way software tools are created and used.

The author will continuously seek for research connections in the field of industrialized construction. Researchers involved in any narrow area of the interconnected industrialized construction processes benefit from the experiences of each other. It will also be necessary to seek researchers and contacts in the field of software engineering and information management.

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CLIENTS AS DRIVERS OF INNOVATION: LESSONS FROM INDUSTRIALISED CONSTRUCTION IN SWEDEN

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In the construction sector, the rate of innovations is perceived to be low. Stakeholder pressure has been identified as an important trigger for innovation. But do Swedish construction clients positively respond to, and thus drive, innovation? The purpose of this paper is to increase understanding of the client's role, as a decision maker, for improving the rate of innovation in construction. This by learning from the case of industrialised construction (IC) in Sweden. Swedish construction clients are generally positive to the expected benefits of IC, but are not actively driving the change towards industrialisation. IC challenges common practice as well as stakeholder expectations and schemata on which decisions are made. Case studies addressing Swedish clients' response to IC show that the uncertainties related to potential future regret are prominent issues. Empirical evidence also indicates high levels of equivocality which, according to information processing theory, cannot be reduced by simply increasing the amount of information. To enable client-driven change, improved information processing capability is suggested. Clients that gather and process information on innovation can reduce bias in decision making. Early adopters of innovations such as IC must also manage high levels of equivocality as the amount of information is low and common practice is challenged. A higher involvement of clients in innovation development is advised.

Keywords: Construction client, Decision making, Industrialised construction, Innovation, Uncertainty

INTRODUCTION

Innovation is necessary for companies striving for competitive advantage and to achieve change within a society striving for sustainable development. However, in the construction sector the rate of innovations such as new technical solutions, new methods of construction and new forms of cooperation is generally perceived as low. In a study on (green) innovation in Sweden, Gluch et al. (2009) concluded that stakeholder pressure is an important trigger for innovation. The construction client has been identified as a key stakeholder in this respect (c.f. UK studies by Abidin and Pasquire 2005; Pitt, Tucker et al. 2009). What about professional Swedish construction clients[2], do they positively respond to, and thus drive, innovation[3]?

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[2] This research focuses on maintaining clients (Frödell, M., P. Josephson, et al. (2008). "Swedish construction clients' views on project success and measuring performance." Journal of Engineering, Design and Technology **6**(1): 21-32.) who build to own, let and maintain multi-dwellings. Both private and public property owner organisations are included.

[3] Innovation, as further referred to in this paper, is defined as ideas, practices and/or objects (processes, products, services, technologies, management approaches) that are perceived as radically new by the

This research focuses on how the client as a decision maker and consequently the decision to invest in new-build is affected by the uncertainty, or even equivocality, surrounding construction innovation alternatives. Can the slow uptake of innovations be explained by how clients make their decisions when information is limited or when established rules of thumb might be inappropriate for evaluating new alternatives? The purpose of this paper is to examine the role of the client decision maker in order to improve the rate of innovation in the construction sector, this by learning from the case of industrialised construction[4] (IC) in Sweden. First, the impact of client uncertainty and equivocality on decision making is discussed based on information processing theory and decision theory. Thereafter, the implications for client response to innovation in the construction sector are discussed based on an analysis of the case of IC in Sweden.

IC, as referred here, focuses on volumetric construction/prefabrication of timber framed multi-dwellings. Among different levels of IC, this represents the most industrialised alternative, or level 4; "complete buildings" as defined by Gibb and Pendlebury (2006). After several Swedish cities burnt down in the late 19th century, timber frames were forbidden in multi-storey (>2 storey) houses and remained so until 1994 when a change in the Swedish building code once again allowed the use of timber. Subsequently, multi-dwelling housing is dominated by on-site caste and prefabricated concrete; thus timber frame represents newness to most clients in Sweden. Höök (2005) concluded that volumetric prefabrication of timber framed multi-dwellings could be classified as a system innovation, presenting uncertainty to the client decision maker.

The paper is based on reviews of; information processing theory and decision theory (with main focus on the influence of uncertainty and biases in decision making); and empirical findings from studies on IC in Sweden (with main focus on studies addressing construction clients). In addition, a re-analysis was made of data files consisting of background data from property owner organisations in Sweden addressing their perspective on IC, collected between the years 2006-2009 (for description of empiric data and methods employed, c.f. Levander and Sardén 2009; Levander 2010; Levander 2010). The discussion is developed by focusing on the general hindrances for making value maximising decisions and the particular influence these hindrances have on client organisations for driving innovation in construction.

A DECISION MAKING PERSPECTIVE ON INNOVATION

The rational model of decision making assumes that the decision maker follows a process of six steps in a fully rational manner (c.f. text books on decision making such as Bazerman 1998; Robbins 2005). These six steps, sometimes conflated to five or three, have been described by numerous researchers approximately as follows: (1) define the problem that needs to be solved, (2) identify all criteria relevant for the decision making process, (3) weight the identified criteria according to their relative

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adopting organisation (herein the client organisation) wherefore the organisation is missing substantial amounts of information (based on e.g. Zaltman, G., R. Duncan, et al. (1973). Innovations and organizations. New York, Wiley, Rogers, E. M. (1983). Diffusion of innovations. New York, Free Press.)

[4] In the UK, the terms 'modern methods of construction' (MMC) and/or 'off-site production' are more commonly used for IC.

value or importance, (4) generate a full list of alternatives or possible courses of action for solving the problem, (5) assess and rate each alternative on each criterion, and finally (6) make the decision by following the result from the computation of which is the optimal (value or utility maximizing) alternative. Although logically appealing to most people, this normative model is based on assumptions that are very seldom fully met.

In the real world, this normative model is applicable for routine decisions where the same decision has been made many times, following an experience based, formal procedure (Butler, Davies et al. 1993). Moving beyond the routine decision, Simon (1957) and March and Simon (1958) suggested that individual judgment is bounded in its rationality.

The modern understanding of judgment is represented by the work of Kahneman and Tversky (e.g. Tversky and Kahneman 1974; Kahneman and Tversky 1979). The more information a decision maker is missing, the more likely it is that the decision maker relies on rules of thumb, i.e. heuristics (c.f. Tversky and Kahneman 1974), to simplify information processing and fill information gaps (March 1994). Although often helpful, these cognitive processes also lead to biases, which explains why decisions made do not follow the suggested normative model and many times do not result in the highest expected utility (Tversky and Kahneman 1974). In their work on prospect theory, Tversky and Khaneman (1979) also discuss how individuals react differently to gains and losses. For example, they found that decision makers are risk-adverse with respect to gains, but are risk-seeking with respect to losses. This implies a higher probability choice is preferred even if it offers lower expected utility than the alternative.

Other biases suggested as playing a strong role in decision making under uncertainty are anticipated regret (Bell 1982) and the status quo bias (Samuelson and Zeckhauser 1988; Ritov and Baron 1992). Referring to, for example Bell (1982) and Kahneman and Miller (1986), Toole (1994) argues that decision makers appear to compare levels of future regret rather than benefits, and that alternatives with relatively higher levels of regret are avoided. More uncertain alternatives are associated with higher levels of potential regret and the reaction of the decision maker is exemplified by Toole (1994, p. 34) in the following illustration: “If a more uncertain alternative was chosen and an undesirable outcome occurred, the decision maker would have a high level of regret (e.g., ‘I knew that was too risky!’) … if the less uncertain alternative is chosen and an undesirable outcome occurred, the regret level would be low (e.g., ‘I really didn’t have any choice since I didn’t know what the other alternative was about.’)”. Empirical tests of predictions from regret theory have provided mixed results; nevertheless, the notion that people take regret into account when making decisions is supported (Zeelenberg 1999). In particular, it is found that decision makers are motivated to avoid post-decisional regret and therefore tend to make choices that “shield them from threatening feedback on foregone courses of action” (Zeelenberg 1999, p. 101). Zeelenberg (1999) discusses conditions inflicting on regret and suggests that the regret will be a more prominent bias when for example trade-offs is implied between important attributes of different alternatives and when the decision cannot be reversed. He also suggests that decision makers tend to discount outcomes that are distant in time and base their decisions on outcomes that are closer in time (see also work on intertemporal choice by e.g. Loewenstein 1992).

When the decision maker is faced with new alternatives, (s)he often sticks with that of current or previous decision, i.e. the status-quo alternative (Samuelson and Zeckhauser 1988). To stick with status-quo could, for example, be about following regular company policy, re-electing a sitting representative or purchasing the same product brands (ibid.). The status-quo bias seems to be stronger when the number of alternatives is high, and weaker when there are strong individual decision maker preferences for an alternative (ibid.). Samuelson and Zackhauser (1988) suggest such explanations for the status-quo bias as presence of uncertainty, transition costs, cognitive misperceptions, psychological commitment, regret avoidance and drive for consistency.

MANAGING BIASES IN DECIDING ON INNOVATION: AN INFORMATION PROCESSING PERSPECTIVE

Prospect theory, regret theory, and status quo bias provide similar theoretical explanations for why people often are biased against choices that offer higher expected utility, but are more uncertain. A decision maker may reject an innovation that provides superior performance and that may have the same chance of failure as the solution currently employed because of the higher level of regret associated with the potential failure of the innovation, whilst a potential failure of the conventional solution is associated with low regret since the decision maker did what he and others have always done (Toole 1994).

Following from these decision theories, Toole (1994) concludes that if uncertainty is high, potential adopters of innovations would rarely adopt without gathering additional information because the decision would probably reflect status quo or regret bias. The bias against a high uncertainty innovation would be so excessive that the existing product or method would always be judged to offer higher relative advantage (Toole 1994). The research by Toole (1994), where he studied homebuilders and their adoption of innovations, showed that those more apt to adopt innovations had superior information-processing abilities related to building innovations, they used more sources of information about new products than did non-adopters, and they involved more functions in making the decision.

Since Galbraith (1973) proposed his model relating structural design to information processing requirements, it has become accepted that the purpose of information is closely related to uncertainty; that is, the purpose of information is to reduce or preferably remove uncertainty. Most decision makers want to achieve certainty in an uncertain world. Bazerman (1998) states that they fail to accept that decisions often need to be made in the face of uncertainty. Galbraith's (1973, p.5) definition of uncertainty is frequently cited and defines uncertainty as: “The difference between the amount of information required to perform the task and the amount of information already possessed by the organisation”. Thus, uncertainty is about lack of explicit information or data, i.e. not having data on defined variables.

To reduce uncertainty, organisations need to enable additional data processing (Galbraith 1974; Galbraith 1977; Tushman and Nadler 1978) and need to ask a large number of questions, acquire information and obtain answers to explicit questions in order to solve known problems (Daft and Lengel 1986). However, an organisation’s situation can often be interpreted in more than one way, and the participants can either find themselves in a position of not knowing what questions to ask, or of there not being any clear answers to the questions asked (March and Olsen 1976). In such cases, one has to deal with equivocality rather than uncertainty (Weick 1979; Daft and Lengel 1986).

Equivocality is about confusion, lack of understanding, disagreement, lack of clarity and ignorance, i.e. not being able to define influencing variables or interpret available information (c.f. Weick 1979; Daft and Macintosh 1981; Daft and Lengel 1986; Daft, Lengel et al. 1987; Weick 1995; Weick 2001). An illustrative distinction by Daft and Lengel (1986) is: “While low uncertainty is about having access to the data that answers questions, low equivocality is about being able to define which questions to ask.”

While uncertainty can be reduced if additional information is available and thus reduce biases and make the decision making more rational, high levels of equivocality implies that the identified problem may not be the problem at all, that criteria may be irrelevant, that ranking criteria is not a relevant task, and so on, and that more data and facts may just distort decision making even more. The solution for resolving equivocality differs from that for reducing uncertainty. Instead of seeking answers, the organization seeks clarification, problem definition and agreement through exchange of subjective views and opinions (Daft and Lengel 1986). Weick (1995) adds that confusion created by multiple meanings (i.e. equivocality) calls for social construction and invention, while ignorance created by insufficient information (i.e. uncertainty) calls for more careful scanning and discovery. Daft and Lengel (1986) conclude that, to reduce equivocality, 'richness of information' rather than 'information amount' is the key. They also provided a conceptual framework for ranking media with respect to their capacity for reducing uncertainty or for resolving equivocality for decision makers. This media richness theory ranges media from the richest (face-to-face meetings and communications) to the leanest (rules and regulations, non-personalised written information). A mismatch between equivocality and richness, i.e. high equivocality and low media/information richness, is suggested as one possible explanation for communication and decision-making failure (Daft et al. 1987). Adoption of innovation should from this perspective not only be a question of gathering and processing high amounts of information, but also about how information is gathered and processed. This argument is consistent with Toole's (1994) findings that adopters of innovation involved multiple functions in the decision making.

CLIENT RESPONSE TO IC IN SWEDEN

IC in Sweden has been put forth as a way to meet clients’ demands for lower costs, improved quality and shorter time frames within construction (Engström, Stehn et al. 2009). With its off-site characteristics and process-orientation, IC is seen as a means to attain advancement in construction (e.g. Statskontoret 2009). IC has also been suggested to contribute to sustainable construction (Jaillon and Poon 2008).

Volumetric prefabrication of timber-framed multi-dwellings, i.e. the IC alternative in this paper, entails all of the identified advantages of IC, such as indoor prefabrication, long-term relationships, less subcontracting, and less specialisation (Nord 2008). Not surprisingly, Swedish clients are generally positive to the expected benefits of IC. However, the clients are not actively drive the change towards industrialisation (Engström, Stehn et al. 2009). For example, according to a governmental investigation (Statskontoret 2009) one of the recurring problems of the construction sector in Sweden is that clients do not facilitate IC, and are, in general, not buying buildings that can be produced in series.

IC challenges common practice in the sector since it encompasses novelty in multiple dimensions: new methods of construction, new forms of organisation and cooperation within the construction process, new and non-local actors, new framing materials and subsequent technical solutions. Even though it could be argued from a contractor point of view that; IC methods have been employed for many years; the forms of cooperation are well documented; the contractors are well established; and the material and technical solutions have been tested, IC differs from what clients are accustomed to and brings about the characteristics of an innovation seen from the clients' perspective, see further table 1.

Table 1: IC brings about the characteristics of an innovation, and thus, challenges common practice – examples from clients' perspective.

Dimensions of novelty in IC	**Example, clients' perspective**
methods of construction	The leading timber framed volume contractors have a prefabrication degree of 80-90 % (c.f. Höök 2008). Hence, the construction process is transformed into a process where industrialised principles for production are employed rather than conventional construction project management practices. Though supporting production control, the construction process becomes less visual and transparent for the client.
organisation and cooperation	General contracts are the most common form of contracts between clients and contractors in Sweden. The industrialised building process, however, implies a design-build contract*, which means that the contractor takes full responsibility for both design and construction. The design-build contract results in design decisions having to be made at an earlier stage in the building process along with altered, and unfamiliar, cooperation forms with contractors.
non-local actors	Volumetric prefabrication of timber-framed multi-dwellings has been driven by small and non-local contractors, as opposed to the local on-site contractors often earlier engaged by the client and to whom relations are already established (Levander 2010).
framing materials and technical solutions	Timber is utilised as frame material in volumetric prefabrication because of the material's high strength/weight ratio and manufacturability, which support factory production and long-distance transportation of modules. To manage the peculiarities of the material and fulfil functional demands, new technical solutions are developed and employed.

Note: * For the contractor, who often incorporates all different trades within one single company, this means an opportunity to make use of the advantages of the industrialised process.

When clients face innovation within construction they are likely to experience not only high levels of uncertainty stemming from lack of data, but also high levels of equivocality stemming from the confusion of different understandings and frames of references. This is found to be the case with IC in Sweden as empirical evidence (Levander 2010) indicated high levels of client equivocality concerning IC, hence cannot be reduced by simply increasing the amount of information. Case studies addressing Swedish clients' responses to IC also show that the uncertainties related to potential future regret are prominent issues. In the data material from a series of studies on client uncertainty concerning IC (Levander 2010), several indicators of anticipated regret is found, see table 2.

Table 2: Indicators of anticipated regret being a prominent issue when making IC investment decisions.

Indicators	**Results found in transcribed interviews from empirical studies presented in (Levander 2010)**
Clients expect negative outcome from already made investment decisions on IC investments	Clients, even those who already had decided on IC, explicitly expressed a fear or anticipation of future regret following on the choice of IC. Clients had considerations concerning the long term performance of timber as frame material as well as the technical solutions presented by the IC contractors. Clients expressed uncertainty with respect to their own ability to evaluate future maintenance needs and costs.
Clients experience trade-offs	For clients, the choice between conventional and IC implies a trade-off between important attributes, for example the trade-off between more well-known, flexible solutions and lower initial costs.
Clients find the definite decision point in IC as problematic	Clients want to be able to make changes along the course of the construction process, something that is not easily facilitated by the employed industrialised process.
Clients discount outcomes that are distant in time and base their decisions on outcomes that are closer in time	Clients' main motive, i.e. decision criterion, for choosing the IC alternative over others has been identified as economic, with an emphasis on the initial construction costs. In addition, lowered credit costs due to production advantages such as short building time on site are mentioned.
Clients are missing information	Clients lack information on IC performance data, e.g. information on the capacity of the timber frame to handle building physics and statics.
The information processing practice (IPP) within the client organisations is not supporting reduction of uncertainty, equivocality or decision-making biases	Decisions are generally made by one or a few individuals from the same department without access to experience data from others since IPP is characterised by: - a lack of communication between the property-development and property-management departments within the organisation - deficient follow-up of running costs (i.e. lack of experience data from property management) on individual properties in stock - inconsistency between goal attainment and investment decision criteria - a neglect to collect and store feedback data from earlier construction projects as well as from operations and maintenance (property) management

The anticipations of future regret could be part of the reason for the slow uptake of IC in Sweden. According to descriptive decision theory, decision makers are biased against choices that are less certain, even if the expected outcome is highly desirable. Consequently, clients are more likely to choose tradition over innovation, even when the latter is considered the better provider of desired outcomes, such as short time spans and low cost. This is also consistent with Toole (1994) who referred to future regret when seeking to explain the slow diffusion of innovations amongst home builders in the US.

In order to enable timely decision making concerning complex issues in complex environments it is necessary to reduce the influence of individual biases and to establish and use a common frame and common decision criteria. These organisational formal rules of thumb, i.e. 'organisational heuristics', are helpful and oftentimes contribute to an effective and efficient decision. The formalisation brought on by these heuristics also help the organisation to reduce equivocality since they guide the individuals in the organisations on what decision criteria to set up and what questions to ask in order to gather the adequate information to evaluate different alternatives. However, these organisational heuristics are based on knowledge and experience of the status-quo alternative, but the more a new alternative (innovation) differs from the status-quo, the more it is likely that these organisational heuristics will bias the decision. This is due to that the organisation are not posing the right questions on the innovation and are not interpreting the available information correctly (not managing equivocality brought on by the innovation). Hence, influencing the decision on innovation is not only individual judgements and biases but also the organisation’s internal procedures which are based on the status-quo alternative. The impact of the organisation’s formal procedures on misunderstanding and misinterpretation of (sustainable) innovative solutions is also discussed by Demaid and Quintas (2006). If client organisations do not take all biases into consideration, individual as well as the built-in organisational, it is more likely that the decision making will result in choosing the status-quo, or the innovation from evaluating the “wrong” decision criteria.

CONCLUSIONS

What is a “good” investment decision made by clients? In this paper it is regarded as one where the client organisation maximises its expected utility/value by gathering and processing information on new alternatives and thus, drives innovation. It is concluded that this is not the actual behaviour of the studied client organisations when choosing between the conventional (status-quo) alternative and IC, the innovation.

As the results from the case if IC have shown, there is a risk that the main decision criterion when choosing innovation will be initial cost. The risk following from this is that clients will drive innovations characterised by lower initial construction cost, rather than by long-term criteria, e.g. improved lifetime quality, reduced life cycle costs or reduced environmental impact. For clients striving for sustainable development this could hardly pass as a good decision or for that matter a good strategy for driving innovation in construction.

To drive innovations such as IC that can change status-quo on a sector level, client organisations must be able to manage high levels of equivocality as the amount of information is low, and common practice is challenged. A higher involvement of clients in early innovation development is therefore advised. Similar conclusions have previously been drawn on project level; e.g. Gibb (2001) stresses that critical information needs to be agreed on by all parties at an early stage in the project, and that the more unfamiliar the stakeholders are with the contents of the project, the more vital is early agreement. However, at this point in time, the client has already made a vital choice on what project to embark, and the IC alternative might have been made impossible to choose.

It should be noted that we have not (yet) studied how decision makers within the client organisations make decisions when they face the choice between the conventional solution and the innovation IC, that is; what functions within the organisation that are involved in the process; how decision criteria are established and; how information is gathered, processed and employed within the decision process. This decision making process has, to our knowledge, neither yet been studied by others. Nevertheless, the client organisations' information processing capabilities will most likely affect decision making, and as suggested by Toole (1994), organisations with high capability can reduce uncertainty and manage equivocality presented by innovations. With this paper we want to shed light on the fact that how client decision makers utilise their information and make their decisions greatly may influence what overall long-term improvements that innovations within construction may entail. We also suggest improved information processing capability within client organisations in order to reduce both uncertainty and equivocality, and subsequently, reduce biases in decision making. Thus, better supporting client driven innovations.

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KNOWLEDGE GENERATION AND BUSINESS MODEL CHANGES: THE CASE OF GREEN CONSTRUCTION

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INTRODUCTION

The general rise of awareness of ecological issues in many markets, together with rapid ICT development around the year 2000, has led to an interest in how "green business models" evolve in a range of industries. Of particular interest is to study such changes in a perspective of knowledge generation across different elements of a business model, including for example Partner Network, Core Competency, Value Configuration and Cost Structure. One important task would be to establish provisional but precise definitions of concepts that are used loosely in the current debate or where the community of researchers has failed to reach a consensus as yet. This problem does not only concern a term such as "green", which is often given definitions that contain the term "sustainable" or "sustainability", which in their turn are difficult to treat without ambiguity, but it is also found in relation to the concept of a business model.

The construction industry is suitable for an investigation of this type because construction projects have a high potential for environmentally adverse consequences. Although green construction is becoming increasingly important, there is no generally-accepted definition on what green construction entails and to what extent firms are successful in this respect. In order for a firm to exploit Green Construction opportunities and gain additional revenue, we expect some changes to take place in its business model(s). Thus, investigating green construction and the changes it brings into elements of a firm's business model would be an important area to investigate in detail. Such changes are often accompanied by processes of knowledge generation in firms.

PURPOSE

The aim is to devise a conceptual structure for exploring how firms change their business models according to knowledge that they generate. The framework thus obtained allows formulating a series of interview questions concerning patterns of knowledge generation that construction-related firms rely on when implementing green changes in their business models.

BUSINESS MODEL ELEMENTS

A business model can be seen as a firm's intended or actual responds to a set of basic questions on how value is created or appropriated (Magretta 2002). In the same vein, a frequently quoted business model definition has been given by Osterwalder et al. (2005). Based on a review of the business model literature they defined a business model as: "... a conceptual tool that contains a set of elements and their relationships and allows us expressing the business logic of a specific firm."

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Their paper is useful for the present purpose because it characterises nine elements (building blocks) which exhaustively cover the business model (see Table 1) and allows separate observation of green construction changes in individual business model elements.

Table 1: Nine business model elements (Osterwalder et al. 2005)

No.	Element	Description
1	Value Proposition	Gives an overall view of a company's bundle of products and services.
2	Target Customer	Describes the segments of customers a company wants to offer value to.
3	Distribution Channel	Describes the various means of the company to get in touch with its customers.
4	Relationship	Explains the kind of links a company establishes between itself and its different customer segments.
5	Value Configuration	Describes the arrangement of activities and resources.
6	Core Competency	Outlines the competencies necessary to execute the company's business model.
7	Partner Network	Portrays the network of cooperative agreements with other companies necessary to efficiently offer and commercialize value.
8	Cost Structure	Sums up the monetary consequences of the means employed in the business model.
9	Revenue Model	Describes the way a company makes money through a variety of revenue flows.

GREEN CONSTRUCTION

The scope and nature of green construction is a heterogeneous phenomenon and is currently not very well defined. A provisional definition of green changes within the context of construction-related companies is defined as changes that bring products and production processes closer to sustainability requirements. Sustainability is usually defined as: "...meeting the needs of the present without compromising the ability of future generations to meet their needs" (Brundtland report, 1987). The emphasis is on use of resources in the future while allowing for contemporary consumption as well. Construction products such as buildings are supposed to stand for long time, so it seems necessary that both process and material which are employed to build a construction product be consistent with environment.

It should be noted that the influential CIB2 (1999) Agenda 21 on Sustainable Construction chose as its starting point for defining the concept the definition proposed by Kibert at the First International Conference on Sustainable Construction in 1994: Sustainable Construction is "the creation and responsible management of a healthy built environment based on resource efficient and ecological principles". According to Kibert (2005), sustainability and green can be used interchangeably.

Green construction is often mixed up with the notion of green building. In English the term "building" can imply both process and product; hence it is necessary to make a distinction between the two. Figure 1 shows different combinations of product-

[2] International Council for Research and Innovation in Building and Construction.

process in green and non-green perspectives. This paper focuses on the green construction process as shown in quadrant 1.

	Construction (process)	Building (product)
Green	green construction	green building
Non-green	conventional construction	conventional building

Figure 1: Product-process matrix in green and non-green perspectives

In order to study changes in business models, alternative objects of investigation might be the whole firm, the entire business model and the relationships among the elements or the elements (building blocks) of the business model. Here the focus is on the relationship among elements of the business model.

METHODOLOGY

Initially sustainability papers and books were identified by an ad hoc list of search words. These publications were studied to understand the topic and to delineate "green construction" in terms of common and important concepts. These concepts were subsequently used to analyse relevant papers and books. The Scopus database was used to search for publications that used one or several of "sustainable, green, environmental, ecological" in their abstracts in combination with one or both of "construction, building."

Papers that were only about the finished building were removed. The focus was on peer-reviewed journal articles, books, reports or printed conference proceedings that were cited in at least three peer-reviewed journal articles. Of these 10 articles or books published between 1990 and 2010 were selected. (see Table 2 overleaf).

KNOWLEDGE GENERATION

There are three ways for a company to generate knowledge: internally, externally or by a combination of both. According to Nickerson and Zenger (2004), in order for a company to generate knowledge there must be a problem to be identified and a search for a solution to the problem. Here the role of manager is highlighted as the one who chooses valuable problems: those which if solved successfully can yield desirable knowledge.

For a firm, there are three approaches to finding solutions for problems: markets, authority-based hierarchy and consensus-based hierarchy, depending on the complexity of the problem. For decomposable problems, firms should rely on market transactions, for nearly decomposable problems on authority-based hierarchy, while finally for non-decomposable problems on consensus-based hierarchy (Nickerson and Zenger, 2004). However, project-based companies can generate knowledge by confronting different potential problems and these can also be relating to one another over time.

Table 2: Elements covered by ten selected publications in green construction

Authors	Elements covered	Comments
Hill and Bowen (1997): "Sustainable construction: principles and a framework for attainment"	1,2,7,9	Economic and Technical sustainability principles
Bartlett and Howard (2000): "Informing the decision makers on the cost and value of green buildings"	8,9	Financial perspective on costs and benefits of green buildings.
Mehta (2001): "Reducing the environ-mental impact of concrete"	1,5,6,8	Cement manufacturing important; how concrete can be environmentally friendly in buildings.
Rohracher (2001): "Managing the technological transition to sustainable construction of buildings"	2, 4, 7	Socio-technical perspective in transition from conventional buildings to sustainable buildings, emphasizing the role of partner network.
Bossink (2004): "Managing drivers of innovation in construction networks"	5,6,7	Identified drivers of construction innovation.
Kibert (2005): "Sustainable Construction"	1,5,6,8,9	More focused on green buildings.
Manoliadis et al. (2006): "Sustainable construction and drivers of change in Greece"	5	Drivers of change in sustainable construction and resources.
Tam et al. (2006): "Green construction assessment for environmental management"	7	Environmental Assessment tools, Green Construction Assessment.
Gluch et al. (2009): "An absorptive capacity model for green innovation and performance in the construction industry"	7	Role of partner network and how it can be a source of knowledge sharing and innovation.
Lam et al. (2009): "Factors affecting the implementation of green specifications in construction"	5,6,7	Stakeholder involvement and technical resources and techniques.

Here, we can distinguish two types of processes for problem identification: analytical and synthetic. A synthetic process, unlike an analytical one, concentrates on external or internal customer demands and needs. The distinction between problem identification (finding) and problem solving is crucial. Do the green efforts of construction-related firms have their emphasis on finding commercially valuable problems, or is it the process of solving problems that they devote more resources to? In a services dominated industry, problem finding often takes place through direct interaction with customers which has strong implications for the direction of search for future solutions. In terms of how resources are devoted, it is probable that problem solving is the more important.

In a problem solving perspective, emerging green construction problems can be seen as potential sources of value. To exploit such opportunities, construction companies would need to generate knowledge from a variety of sources so as to exploit the potential value embedded in the problems. As a consequence, the exploitation of the new knowledge may require a change in one or more of their business model elements.

For firms active in the manufacturing industry, analytical processes for problem identification and hierarchical internal structures combined with markets for problem solving is expected. For firms active in service production, it is probable that both problem finding and problem solution involve interaction with their external customers. Knowledge intensive business service providers are expected to rely on synthetic processes for problem identification, and their solution finding might contain elements of both markets and consensus-based hierarchy.

Which is the degree of difficulty associated with the potentially valuable problems that are identified by the firms? The process of problem solving can be characterized by its technology aspects and its customer or market aspects. In the special case of construction contractors, which seldom face a mass market and where customers tend to present them with extensive specifications of what they wish to see built, the greatest difficulty might lie in persuading customers to demand new solutions to their problems.

It is probable that construction-related firms representing different governance types can be identified; traditionally, heavy manufacturers of construction materials and components have tended to be hierarchically organized, whereas construction contractors, in particular general contractors, tend to rely mostly on market relationships. Therefore, we should expect to find firm-specific search patterns associated with specific changes in business model elements.

With a focus on the relation between problems being decomposable and the difficulty of their solution, we should expect integrating firms to be highly skilled at decomposing problems but not at performing a subsequent stage of in-house problem solution; if there are no easily available solutions to one or more components of the decomposed problem to be found in the market, the difficulty may remain high.

The following section will synthesize the findings from the brief literature review. This paper has identified literature streams that we arguably are relevant to analyse the relationship among business model changes and knowledge generation when firms become ‘greener’.

DISCUSSION AND CONCLUSION

The framework proposed here is intended to serve as a support for formulating questions for exploratory interviews with firms in the construction sector. The interviews could be semi-structured and retrospective for e.g. a three-year period, concentrating on commercial experiences of what the firms have perceived as green changes in their business models, and then working backwards in order to trace the nature of the problems as they were understood originally by the firms. From that point of origin, the paths of knowledge generation can be studied.

According to Slack et al. (2005), there are five main production process types: project, jobbing, batch, mass and continuous. Construction-related firms except manufacturers of e.g. cement mostly have processes that belong to the project type. Business models in project-dependent industries can be expected to have particular characteristics. Their target customers are often clearly identified and even involved in the production process, which is associated with close relationships. If the customer is highly active in determining the characteristics of the project product, it is not unlikely that the revenue model is more or less of an auction type, where the project-dependent firm may engage in low-cost bidding, if not lowest cost, as with some government clients traditionally.

Innovation in construction-related firms often resembles innovation in the service sector (Bröchner, 2010). It is mostly incremental in nature and does not show a rapid pace, and every time a new project gets started, conditions of these companies change. This gives more flexibility to project-based companies than other types of companies;

hence potential problems they might identify and solve are different from large-scale manufacturing.

Based on the conceptual framework presented here, it is likely that the following statements hold true:

1) In general, there are specific patterns of knowledge generation associated with combinations of (a) the complexity of the problem, (b) element of the business model, and (c) the type of firm.
2) In the special case of Green Construction and green changes in business models, there will be a subset of combinations which will apply only to the conditions that are typical of construction-related firms, probably and ultimately reflecting the durability and immobility of the tangible products of the project-oriented construction process.

One important issue is that while new knowledge is required to change business models, it is difficult for managers to search directly for new valuable knowledge; instead they need to focus on valuable problems that when solved lead to new valuable knowledge. The complexity of the valuable problem determines the organization of search for new knowledge, i.e. the problem complexity determines at least to some extent the set up of the business model.

Some, but not all of 'green problems' will change the complexity of the problems that construction-related companies address. When new problems emerge or old problems, change because of internal and external demands of becoming greener, we suggest that these problems tend to be more complex than before. This will shift search patterns from directed search to heuristic search, so that decomposable problems may become nearly decomposable or non-decomposable, while nearly decomposable problems will become non-decomposable. This means that problem-solving by means of market relations will shift into either consensus based or authority based organization within the company, or towards network relations with complementary players. However, the exact impact of these changes will depend on the type of firms. We argue that companies that solve client problems by partly contracting out problem-solving will need to either create new competencies in-house or network more closely. The more complex the green issue, the greater the effect on the organization of these companies.

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THE BUSINESS MODEL EFFECT ON COLLABORATIVE PRODUCT DEVELOPMENT IN SME CONSTRUCTION COMPANIES

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The housing construction industry in Sweden is fragmented with few major actors dominating the housing market and several local or regional small and medium (SME) sized construction companies. This combined with the SME's lack of resources for knowledge consuming activities such as product development and innovations, creates a super competitive situation for the SME companies. Studies shows that innovation and business model are tightly linked to each other. A business model that is robust can be used as foundation for innovation. The business model needs to define the market, partnerships, product attributes meeting market requirements and production parameters such as cost, time and quality, which are all necessary input for achieving product innovation. This paper investigates a SME construction company and its suppliers, initially linked by traditional working agreements, when developing a product collaboratively in order to gain increased market shares. This paper elaborates on whether developing the business model might be a possible key success area for SME construction companies, which might enhance their possibilities in offering a more competitive product to the market. The objective is to find a methodology that is applicable and workable for the SME's in construction industry and to develop a framework for analysis. The work described in this paper aims at improving our understanding of the SME product development process. The result of the product development project has been a new design process with a business model that has longer contractual agreements rather than short-term project procurement.

Keywords: product development, supply chain management, business development, innovation.

INTRODUCTION

The housing construction industry in Sweden is fragmented with few major actors dominating the housing market and several local or regional small and medium (SME) sized construction companies (See Table 1). The housing construction industry is focusing on product development and specially companies working with off-site production. Off-site production is driven by product development and focuses on the design process which implies the need of using resources earlier than on the actual construction site (Björnfot and Stehn 2007).

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Table 1: The EU Commission adopted Recommendation 2003/361/EC regarding the SME definition. Enterprises qualify as micro, small and medium-sized enterprises (SME) if they fulfil the criteria. In addition to the staff headcount ceiling, an enterprise qualifies as an SME if it meets either the turnover ceiling or the balance sheet ceiling, but not necessarily both

Enterprise category	Headcount	Turnover	or	Balance sheet total
medium-sized	< 250	≤ € 50 million		≤ € 43 million
small	< 50	≤ € 10 million		≤ € 10 million
micro	< 10	≤ € 2 million		≤ € 2 million

SME development capabilities can be characterized as having few resources for development and the daily work of managers and key-personnel is hands-on and without support in the initial phase when the business model is defined. The companies also seems to lack the ability to execute their strategies (Elmhester 2008).

Compared to large companies, the SME manager, often the firms's owner, does not have extended management team representing the different competencies needed (Ylinenpää 1997). Multiple responsibilities are often handed to one person.

This means that the SME often lack the resources or time needed for structured product development. The consequence being often that the manager decides based on a feeling when and how to develop a product (Pitta, 2008).

At the same time, studies shows that innovation, product development and business model are tightly linked to each other. A business model that is robust can be used as foundation for product development and innovation (Ylinenpää 1997).

According to Ylinenpää (1997), the importance of small firms was more or less ignored for decades even though small enterprises in Europe are at least 95% of all enterprises. But the political climate has changed and the large mass producing industries rationalisation has an expectation to be compensated by the SME sectors. Small business development importance has been underlined by two studies; in Sweden 78% of the net growth of employment during the period of 1985-91 was created by small businesses employing 1-19 persons and during the economic recession between 1990-93 and the turn-around which took place in 1994, these results were confirmed (Ylinenpää 1997).

This paper investigates a SME construction company and its suppliers, when developing a product collaboratively in order to gain market shares in a cost-efficient way. The idea of network capability as influencing competitiveness positively is supported by Parida (2010). The scientific purpose is to develop a framework for understanding how the product development process in SME construction company can be enhanced, and to build a theoretical model for analysis. The investigated project has been a collaboration project between a traditional house manufacturer and its suppliers. The project members were assumed to participate and share the responsibility for product development.

The fact that SME companies operate in an environment that gives little opportunity to structured research and development, which might be the basis for product development, gives an understanding of the methodological challenge in production innovation at SME companies. The other reason why it is important to investigate SME competitiveness is that it seems that SME´s plays a large role in net growth employment and especially during economic recessions.

The hypothesis of this paper is that a possible key success area for an SME, is developing their business model as a way to enhance their possibilities to offer a more competitive product to the market. The objective is to find a methodology that is applicable to the SME in construction industry; a systematic and practically doable approach for developing competitive products and managing them during their life cycle.

METHOD

A qualitative case study focusing on the **product development process** was conducted, whose analysis was based on the approaches discussed in the preceding section of this paper; the sources of the data analysed are shown in Table 1. The process was led by a Swedish off-site timber construction company. The company produces detached dwellings for leisure and for single- or family-occupancy; the dwellings are constructed using pre-fabricated elements that are assembled on-site.

The construction company invited eight suppliers to collaborate in the design and production of single family housing for the B2B market. Rather than using a traditional approach to development, the idea was to collaborate, i.e., the suppliers were to become part of the product development process and design input was provided by architects and potential clients. It was anticipated that collaboration would lead to a more competitive housing design and a more efficient and innovative supply chain. The product development process was conducted during a series of joint meetings, supported by the authors.

Table 2: Sources of data obtained during the case study.

Data collection	Number
Interviews	12
Group Interviews	7
e-mail	1358
Value Stream Mapping	2

The construction company co-operates with a limited number of key-suppliers, but the nature of its products implies that they work with a broad client base. The complexity of housing products and processes are, if we disregard from the fact that a pre-fabricated house contains a lot of components, generally low. Product development, besides normal client adjustments, is at present non-existent. The typical competence in the project group is represented by blue-collars, either fabricating different types of houses having only a compulsory school background or two years from a practical upper secondary school. Some of the managers holds higher, although not university, qualifications.

THEORETICAL FRAME OF REFERENCE

The theoretical frame of reference for our analysis has been SME company development and product development in small firms and also business model theories.

SME characteristics

Stage gate evaluation is often described as necessity for product development, but smaller companies do not normally employ these. In smaller organizations, such ideas may make it to the introduction stage without being evaluated with a rigorous stage-gate process. (Pitta 2008)

SME companies also often operates in an external uncertainty of the environment that is often greater than in large firms, but compensated by internal understanding and consistency of the firm's goals, strategies and actions. In small firms ownership, management and control are normally integrated and personified by the owner-manager, implicating a more simple and effective decision-making process. This facilitates for a small firm to operate in a more flexible manner than a larger firm, which is often tied up by formal plans, expectations from external shareholders, and a more complicated decision-making process (Ylinenpää 1997).

It might even be so that that a small firm, due to a greater external uncertainty, is more exposed to utilize flexibility as a competitive weapon. This flexibility is understood to be characterized by a more reactive decision-making style and informal planning, often formed more by emergent than deliberate strategies. (Ylinenpää 1997)

Product Innovation

(Pitta 2008) refers to Cooper, R. (1999), "From experience: the invisible success factors in product innovation", Journal of Product Innovation Management, Vol. 16 No. 2, pp. 115-33) the "correct" process for identifying good product concepts and shepherding them through the product innovation process. Companies and individuals who ignore them run a higher risk of failure than those who follow them. The reasons that not following the factors means that the process is on a path to higher risk. Cooper (1999) reported perhaps the most succinct set of factors that are:

1. Solid up-front homework – to define the product and justify the product.
2. Voice of the customer – a slave-like dedication to the market and customer inputs throughout the project.
3. Product advantage – differentiated, unique benefits, superior value for the customer.
4. Sharp, stable and early product definition – before development begins.
5. A well-planned, adequately-resourced and proficiently-executed launch.
6. Tough go/kill decision points or gates – funnels not tunnels.
7. Accountable, dedicated, supported cross-functional teams with strong leaders.

The implication is that when the situation becomes more complex, defined as a higher level of competition, more and more complex products, more regulations to follow, and more customers to serve, the need for planning, formalization, goals, and objectives increases. (Pitta 2008)

The business model

The business model describes the business logic and gives a direction how business creates and delivers value to customers. Is also defines the basic structures of revenues, costs and profits connected to the company delivering the value. "In essence, a business model embodies nothing less than the organizational and financial 'architecture' of a business" (Teece 2009)

Business models are often sprung out of by technological innovation which creates both the need to bring discoveries to market and the opportunity to satisfy unrequited customer needs. At the same time, new business models can themselves represent a form of innovation. Figuring out how to deliver value to the customer and to capture value while doing so are the key issues in designing a business model: it is not enough to do the first without the second (Teece 2009).

But developing a successful business model is insufficient in and of itself to assure competitive advantage. In practice, successful business models very often become, to some degree, 'shared' by multiple competitors. Having a differentiated (and hard-to-imitate) but at the same time effective and efficient architecture for an enterprise's business model is important to the establishment of competitive advantage.(Teece 2009)

In short, innovating with business models will not, by itself, build enterprise-level competitive advantage. However, new business models, or refinements to existing ones, like new products themselves, often result in lower cost or increased value to the client; if not easily replicated by competitors, they can provide an opportunity to generate higher returns to the pioneer, at least until their novel features are copied.(Teece 2009)

RESULTS

Due to the imbalance of size in the market the construction company invited its suppliers to collaborate in a product development process.

The collaboration project ran into a number of early problems. The first product developed by the group seemed to have no value for the client, and it rapidly became apparent that the group did not have a well-defined target client for their product. The project team then decided to use a product development method used by small companies, but quickly became troubled by the price of the new house design. The technique of target costing was tried, but as it was unfamiliar to many of the participants, it did not prove useful. These problems led the group to consider questions of collaboration, such as "How should the collaboration agreement look like?" and "Should we start a new company together" and "Who owns the business model and the client". The project group began to lose focus, and the contractor decided to slow down the development.

The suppliers did not seek to play an active role in the design process, and were content to sit back and wait for an order to produce, which is the way they are used to working in traditional construction.

The business model together with the ability of systematically working with client needs and requirements and the use of common and communicated objectives in a product development team seem to affect the supplier willingness to participate in product development process.

ANALYSIS

To understand and to visualize when and in what kind of situation the group came to certain conclusions, a matrix for SME development areas and for the development process where used for drawing a roadmap.

The model, figure 1, for analysis is based on both the theoretical frame of reference and empirical observations.

The matrix is based on established and agreed development areas that has been used by organisations focusing on regional growth by SME´s for more the five years, which means that SME companies are well familiar with this categorisation. The development process, on the other hand, aims at visualising important events and the necessary decisions between these events, for example the decision for starting to plan the development of something new. This model was originally developed for supporting communication.

The model, figure 1, for analysis is based on both the theoretical frame of reference and empirical observations.

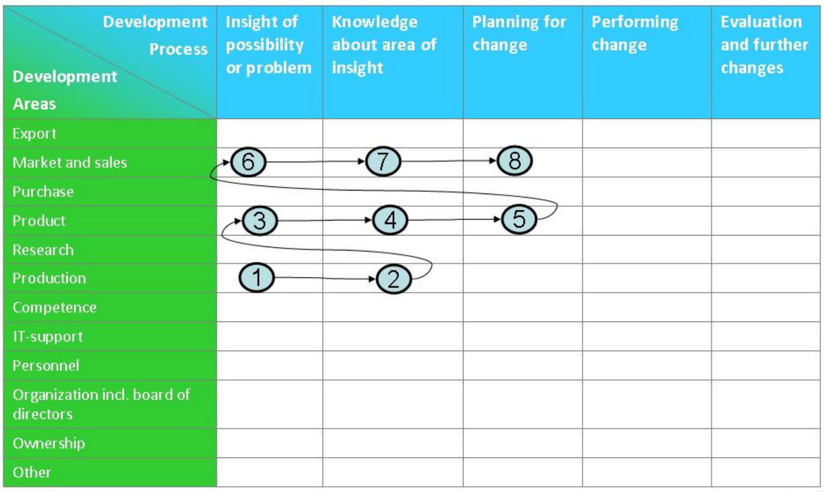

Figure 1: Model for analysis. The model is used as a practical road map used for both discussing and identifying potential developments areas and for identifying where in the development process a SME Company or a specific person is situated.

The generic areas for business models are: Export, Market and sales, Purchase, Product, Research, Production, Competence, IT-support, Personnel, Organization incl. board of directors, Ownership, Other.

The knowledge accumulated is divided into: Insight of possibility or problem, Knowledge about area of insight, Planning for change, Performing change, Evaluation and further changes.

When analyzing the path made by the project group, figure 1, one can state that this might be a typical case for a product development project or any development project. The project group initially approached the problem as a normal production or supply chain problem, with the purpose of making the production more cost efficient.

However after gathering knowledge the group came to the conclusion that they needed a defined product in order to make the supply chain more efficient, which then moved them on to product development. , Once the project group started to learn more and after a while when planning the product production phase and entering product calculation the question “what is the client willing to pay for this?” rose and after that shortly “who is the client”. This gave the insight that the group lacked selling capacity and also that they lacked market focus

Could the group have shortened the project life cycle if used the model in figure 1?

DISCUSSION AND CONCLUSIONS

The work in the project has focused mainly on criteria’s for achieving competiveness through supplier involvement in the product development process. The conclusion is that the business model has to be more innovative and change from short term contracts and focusing on the lowest bid to long term contracts and the supplier adding value. In fact the business model is probably the main success factor. Then the company needs to look that in their business model that has to be developed; product, production, sales or IT-support and innovate within that area in order to create a win-win situation in the collaboration project.

However, the results do not conclusively prove or disprove the hypothesis. The analysis shows that it is reasonable to assume that business model heavily effect the different processes in a company and specially product development. However, further work is required to obtain a deeper understanding of the effects and the ways in which they are interrelated. Further research is needed both to define the model but also to verify it accuracy.

The research project moves on in order to elaborate on the key areas in order to find a more accurate model for competitive product development in a collaborative research project. All business has to have defined business model since it is that it defines how clients are willing to pay for your product and how you should operate your organization in order to maximize your profit.

The model has its obvious weakness in the areas chosen for the business model. They might be too broad and in that sense they might not pinpoint the accurate problem. Further research is needed to define the areas on the y-axis. In similar way the x-axis corresponding to the learning curve. The model needs to be built on more theory. If using a lean tool like 5 why’s it might be that the model could steer an innovation project to the right questions to answer. It might not always be the obvious.

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