Applicability of Continuous Improvements in Industrialised Construction Design Process

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“It requires a new way of thinking to solve the problems we created with the old way of thinking”

(Albert Einstein)
PREFACE

This thesis is the result of two years as a PhD student at the Division of Structural Engineering – Timber Structures, Luleå University of Technology. During this period, a lot of people have contributed in various ways and therefore I would like to take the opportunity to show my sincere appreciation;

The personnel at the main case company for the commitment and support they have demonstrated although this project. I would like to personally thank the following persons for their contribution in terms of time, effort and knowledge sharing: Lars Atterfors, Johan Samuelsson, Mikael Hedtjärn, Henrik Ödeen and Erling Lind. An extra honourable mentioning is directed to Lars Sörsjö, my industrial supervisor, who has been invaluable for my understanding for industrialised construction design process.

The companies and respondents which have participated in the case studies and the survey and provided me with valuable empirical data and industrial perspectives, and the competence centre of Lean Wood Engineering for the financial support. Without you this research would not have been possible.

My three supervisors Professor Lars Stehn, Associate Professor Helena Johnsson and Doctor Marcus Sandberg for guidance and support during this journey. I feel privileged to work with you and I am looking forward to future collaborations.

My colleagues and friends at timber Structures for making everyday work both interesting and fun, making me realise how fortunate I am to be surrounded by talented and dedicated people.

Finally, I would like to thank my beloved family to have put up with an absent family member. My three sons, William, Felix, and Herman, who have been my source of energy when thesis writing has been too intense at times. My wife Petra, for keeping things together and filling my life with love and joy. I look forward to spend the rest of my days making it up to you. “From first moment…” “…to final breath”.

Erik Söderholm
Luleå, February 2010
The construction design phase is currently the most time consuming part of the industrialised construction process and the bottleneck for further streamlining the process at most industrialised construction companies in Sweden. One explanation is that every construction design project is considered as something new and unique, wherefore use of experiences to promote continuous improvement is limited (Meiling 2008).

Höök (2006) argues that industrialised construction companies have the potential to progressively extract experiences from projects and incorporate them as knowledge into standardised processes. Improved performance is of interest for every company, since high performance implies high competitiveness, which in turn gives high profit. Slack et al. (2004) state that any operation, regardless of how well managed, still have the potential to be further improved.

The aim of the research is to investigate the applicability of continuous improvement to the industrialised construction design process.

Empirical data has been collected in two case studies and one survey, which has resulted in three appended papers with focus on: construction design organisation, performance measurements, and the building system. Each paper contributes to the comprehensive aim, but focuses on various aspects of the construction design process.

The results show that having a rigid organisation, with the same personnel from one project to another, is favourable when working with continuous improvements. The current performance measure is not considered to support continuous improvement work, as comparison across different project-types is difficult. It is also impossible to determine the effect of improvement initiatives using total time spent as a performance measure. The results also show that the documentation of the building system is limited wherefore the building system cannot serve as a bearer of information, which is obstructing work with continuous improvements.

The general conclusion is that continuous improvements are considered applicable to industrialised construction design process with minor restrictions in terms of better documentation of the building system and adapted performance measurements.
SAMMANFATTNING

Projekteringen är för närvarande den mest tidskrävande delprocessen i industriellt byggande och utgör en flaskhals för att optimera hela processen hos de flesta industriella byggare i Sverige. En förklaring är att varje byggregn som nytt och unikt, varför erfarenhetsåterföring som understöder ständiga förbättringar är sällan förekommande (Meiling 2008).


Syftet med forskningen är att undersöka om ständiga förbättringar kan implementeras i projekteringsprocessen i industriellt byggande.

Empiri har samlats i två fallstudier och en enkätestudie, vilket har resulterat i tre artiklar med fokus på: projekteringens organisation, produktivitetsmått och byggsystemet som strategisk tillgång. Varje artikel bidrar till det övergripande syftet, men fokuserar olika aspekter av projekteringen.


Den generella slutsatsen är att ständiga förbättringar kan implementeras i industriellt byggande med mindre justeringar som avser bättre dokumentation av byggsystemet och anpassade produktivitetsmått.
APPENDED PAPERS

Paper I:
Proceedings of the 24th Annual ARCOM Conference, September 1-3 2008 Cardiff, UK.

Paper II:
Proceedings of the 25th Annual ARCOM Conference, September 7-9 2009 Nottingham, UK.

Paper III:
Söderholm, E. and Johnsson, H. “Building System as a Catalyst for Change from Project to Process Orientation”. 
(Submitted for publication in Journal of Construction Engineering and Management in February 2010).
1. INTRODUCTION

In this chapter the background to and purpose for the thesis are presented followed by the aim and research questions. Finally the disposition of the thesis is outlined.

1.1. Background and problem description

The construction design phase is currently, as shown in Figure 1, the most time consuming part of the industrialised construction process and the bottleneck for further streamlining the process at most industrialised construction companies in Sweden. One explanation is that every construction design project is considered as something new and unique, wherefore use of experiences from previous projects is limited (Meiling 2008). The construction design process is part of every construction project where client requirements (the input) are transformed into, production parameters (the output).

Having a construction design process that differs considerably from one project to another is not desirable when improved performance is targeted. This has led to an interest in how Lean Production and Lean Thinking can be adopted in construction to improve the production system and management of the supply chain (Naim and Barlow 2003; Höök 2008; Höök and Stehn 2008).

Figure 1. A schematic representation of the value chain in industrialised construction. Based on Meiling 2008.

Höök (2006) argues that industrialised construction companies have the potential to progressively extract experiences from projects and incorporate them as knowledge into standardised processes. To facilitate learning from previous experiences in a systematic manner is seen as vital for achieving success regardless of what context or industry a company is active in (Landin 2000). Josephson (1994) has identified fragmented organisations and production processes as explanations to
the difficulty in knowledge transfer and learning in between projects in the construction industry.

Lessing (2006) studied the process structure and management of industrialised construction in a holistic view and identified design and production preparation as one of the sub-areas of the construction process where further development is needed. Also Höök (2008) has identified two elements of the construction design process, information flow and loyalty to building system, as two areas in need of improvement for industrialised construction industry. This implies a need for the industrialised construction sector to address the question of how the construction design process can be improved.

Improved performance is of interest for every company, since high performance implies high competitiveness, which in turn gives high profit. Slack et al. (2004) state that any operation, regardless of how well managed, still have the potential to be further improved. There are several aspects of a company that can be subject to performance improvement, e.g. equipment utilisation, organisation, lead-times, product quality, scheduling or inventory levels. Furthermore, market fluctuation, arrival of new technology or other changes in the environment require an organisation to make adjustments. These adjustments can be made either in small incremental day-to-day activities or in larger fundamental changes.

Industrialisation of the construction process can be considered a radical change, an attempt to address a number of the identified problem areas in the Swedish construction sector. This construction sector has been reported as inefficient and slow in adjusting to changes, and in urgent need of improved product quality and financial results (SOU 2000; SOU 2002). Swedish construction companies generally overlook the opportunity to assimilate knowledge from previous projects with a systematic approach (Borgbrant 2003; Forsberg and Saukkoriipi 2007).

By adopting an industrial approach to construction the industrialised construction companies have changed focus from one-off production to prefabrication of products with various degrees of specialisation (Lessing et al. 2005; Goodier and Gibb 2007). This change in strategy transforms the construction companies from object-oriented, on-site construction firms, into process-oriented off-site manufacturers with increased control of the value chain (Höök 2008). By taking charge of the entire value chain, from sales to completion on the construction site, these companies are able to work with
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continuous improvements of their processes and reoccurring interfaces (Jansson et al. 2008).

The rationale of industrialised construction requires both controlled products and controlled production processes where consideration of the entire value chain is taken in every task and activity. For this reason the industrial construction companies have company-unique building systems to regulate how the products are realised. The building systems are based on experiences the construction company have made in previous construction projects. Typically the documentation of the building systems is containing standard solutions (components) and detail specifications (joints). The standard solutions provide detailed descriptions of how components are constructed while the detail specifications explain how connections between different components are made. Both the content and the degree to which the building systems are documented differ significantly between different companies. Common for all industrial construction companies is that the building systems are central and a determining factor both in everyday work and in strategic development of the company.

1.2. Industrial construction industry in Sweden

Industrialised construction is a part of the Swedish construction industry that is considered to have the ability to increase efficiency and product quality as well as lowering the costs (SOU 2002). Brege et al. (2004) state that the industrialised timber housing sector has the potential of saving costs of up to 30 % and also improving the quality as a consequence of moving the production from construction sites to industrial manufacturing in a closed environment. The industrialised construction companies that base their production on timber framed volumetric element prefabrication to produce multi-storey houses and commercial buildings, currently hold a 10 % market share of the Swedish market.

In Sweden, the development of industrialised construction methods has mainly been driven by small to medium-sized construction companies. The companies have developed toward higher degrees of industrialisation in a consistent but moderate pace.

Gerth (2008) reports attempts of creating an industrialised construction process with both steel and concrete, but both attempts were considered as failures. The letdowns have been explained by the companies moving ahead too fast without having the required knowledge but also that they had a lack of patience for financial results.
Lessing (2006) have a comprehensive view of industrialised construction and defines it as;

*Industrialised house-building is a thoroughly developed building process with a well-suited organization for efficient management, preparation and control of the included activities, flows, resources and results for which highly developed components are used in order to create maximum customer value.*

Industrialised construction can be perceived as being in the cross-section of construction and manufacturing industry, Figure 2.

![Figure 2. The industrialised construction industry in the cross-section of construction and manufacturing industry. Based on Meiling 2008.](image)

Gibb (2001) stresses that industrialised construction is somewhat opposite to traditional site-based construction merely transferred into a factory environment, wherefore practices and culture must be challenged in order to reflect the manufacturing culture. A clear contrast is that construction industry generally is project-oriented, where unique, one-off products are produced during a limited period of time. The manufacturing industry on the other hand is generally more process-oriented, meaning the production includes large series of products, produced over longer periods of time.

It is evident that the construction design process plays a key role in industrialised construction as the holistic approach requires getting everything right from the start.

The main objective of the design phase is to translate the customer requirements to production parameters, a task that involves taking
interests of the entire value chain into account. The design department is also responsible for scheduling the production and assembly phases, where labelling the building parts is a crucial part of certifying the flow of material throughout the entire process. Coordination of installations such as ventilation, HVAC, and electrical installations is another important task.

The construction design process is generally divided into two distinct phases; building design and detailed component design. The first phase is initiated after a conceptual model of the object has been developed. This is done by an architect that can be either in-house or external. The construction design team generates 3D-models on sections, floor plans and basic plans, using CAD software, enabling other resources to initiate their work. Before the project is developed in detail, the drawings are sent to the client for approval. After the drawings have been approved by the client, the second phase begins involving detailed development of the components of the building. The detailed component design generates drawings to the production and specifications of material which are handed over to the purchase department. The construction design process is considered complete when the component drawings are delivered to the production department.

1.3. Research motives

The underlying project to this thesis, “Standardised Design Process” is founded within the undeveloped research area of industrialised construction. The project has a decisive starting point in the view of industrialised construction design as something different from ‘traditional construction design’. The idea is to establish a construction design process that is stable regardless of construction project, where knowledge can be constantly captured and increased and where performance can be measured in order to predict, control and evaluate the results of the process.

In order to pursue this idea, an investigation of the applicability of continuous improvement and performance measurement to the industrialised construction industry was considered proper. Research about learning within the construction context has stressed the importance of capturing project experiences and integrating it into the processes of the organisation in order to facilitate improvement, wherefore also the feasibility of applying these theories to the industrialised construction context is investigated. As previously identified by Lessing (2006) and Höök (2008), further investigation of
the construction design process and its elements within the industrialised construction context is needed.

To summarise, the previous research in the area of industrialised construction is in general limited, where research about the construction design process in particular is absent, indicating a research gap.

1.4. Aim and research questions

The comprehensive aim of the research included in this thesis is to:

*Investigate the applicability of continuous improvements in industrialised construction design.*

The thesis consists of three appended papers and this cover paper. Each paper contributes to the comprehensive aim, but focuses on various aspects of the construction design process, resulting in several theoretical and empirical perspectives. Every appended paper has its own specific aim but contributes to the holistic view presented in the cover paper. Paper I examines different strategies for organising the construction design process through a Lean production perspective. Paper II investigates how the current practice regarding the use of performance measurements in the construction design process correspond to characteristics found in literature. Paper III examines which role the building system plays in moving from project based construction design process into a process-oriented one.

To reach the comprehensive aim of the thesis the following set of research questions were developed:

**Question A:** How does the construction design process organisation affect the work with continuous improvement?

**Question B:** How can continuous improvement of the construction design process measured?

**Question C:** What is the role of the building system for continuous improvement?
The research presented in this thesis is designed as a case study where the construction design process in industrialised construction is focused. For detailed information about the research methods used and the case company, see chapter 3 Methods.

1.4.1 DEMARCATIONS

To enhance the understanding of how the construction design process within industrialised construction can be improved, the theories of continuous improvement (kaizen) have been studied. The use of continuous improvement theories is in literature often as a part of a larger theoretical framework such as Lean production or Total Quality Management (TQM). In this study, the field of TQM has been excluded, since the focus of the underlying project is not placed on improvement of quality but performance. In this thesis, continuous improvement is seen as an improvement management program, used with a tool-based approach.

Theories of Lean production are included in this thesis, but not in detail. The Lean theories are used more as a comprehensive philosophy than a tool for step-by-step improvements. The essence of Lean that is included in this thesis is the notion of always striving for improved performance, the critical questioning of current methods, standardisation of work procedures and the awareness of long-term commitment.

The performance measurement theories are included to enable measurement of the results of the continuous improvement, not the performance in total. Learning as a concept is included in this thesis merely to reflect how the knowledge generated in continuous improvements can be captured within the company, wherefore learning theories have not been studied in detailed.

The research included in this thesis is limited to only considering the industrialised housing market in Sweden and is further limited to only study the construction design process in detail at one main case company. Both the choice of case study as research design and the choice of one main case company affect the result and the conclusions.
1.5 Thesis disposition

The thesis consists of two parts where the first part is the cover paper including Chapter 1-6 are listed below and a second part comprising three appended papers. The content of the cover paper is:

Description of chapter 1-5:

**Chapter 1:** Introduces the reader to the research field, presents the motives, aim and research questions as well as guides the reader through the disposition of the thesis.

**Chapter 2:** Presents the theoretical framework and a model of analysis that will be used in chapter 4.

**Chapter 3:** Presents the chosen research methodology and the different methods used in collection of empirical data.

**Chapter 4:** Presents and analyses the empirical results from papers I-III.

**Chapter 5:** Discusses the result in relation to papers I-III and the theoretical framework in chapter 2 and draws conclusions from findings related to the aim, provides answers to the research questions and proposes future work.
1.6. Appended papers

Paper I: *Design Process Organisation at Industrial House Builders – A Case Study of Two Timber Housing Companies in Sweden*  
Written by Erik Söderholm, Gustav Jansson and Helena Johnsson, published in Proceedings of the 24th Annual ARCOM Conference, September 1-3 2008 Cardiff, UK. Erik Söderholm’s contribution was co-planning and performing the process mapping and the interviews. All authors contributed to conceptual ideas for the Paper. The paper was written by Erik Söderholm and Gustav Jansson under the supervision of Helena Johnsson.

Paper II: *Housing Design Performance – How is it Measured?*  
Written by Erik Söderholm and Helena Johnsson, published in proceedings of the 25th Annual ARCOM Conference, September 7-9 2009 Nottingham, UK. Erik Söderholm’s contribution was formulating fundamental ideas, conducting the literature study, planning and performing the interviews. The paper was written by Erik Söderholm under the supervision of Helena Johnsson.

Paper III: *Building System as a Catalyst for Change from Project to Process Orientation.*  
Written by Erik Söderholm and Helena Johnsson, submitted for publication in Journal of Construction Engineering and Management in February 2010. Erik Söderholm’s contribution was formulating fundamental ideas, conducting the literature study and capturing and writing the results in the form of a case study. The paper was written by both authors.
2. THEORETICAL FRAMEWORK

In this chapter the overall theoretical framework for the thesis is presented. The framework includes the following areas: Continuous improvement, learning organisation, performance measurement and Lean production. In the end of the chapter is the model of analysis presented.

2.1 Contents of the theoretical framework

This section is included to explain how the four areas included in the theoretical framework interrelate. Focus of this thesis is placed on improvements wherefore the theoretical field of continuous improvements is explored as a methodology for problem solving and performance enhancement of the industrialised construction design process. Performance measurement is included as a methodological element used for evaluation of the result of improvements initiatives.

Also the theories of learning organisation are included as a methodological element to address how learning and knowledge can be captured with a systematic approach. Lean production theories are in this thesis seen as a comprehensive improvement program, but in terms of being a philosophy rather than a tool for gradual improvements.

2.2 Continuous improvement

Improvement is a central part in popular management concepts such as Lean Production, Total Quality management (TQM) and Business Process Reengineering (BPR) and have therefore gained interest in previous research (Bond 1999) Juran and Gryna (1988) define improvement as attaining a new level of performance that is superior to any previous level.

According to Imai (1986) improvements are defined by the Kaizen, (in Japanese “Kai” is change and “zen” is good), in combination with innovations. Kaizen involves maintaining and improving the work-standard in small incremental steps while innovation refers to improvements as a result of large investments. It is important to distinguish between innovation and Kaizen, where the former is more active as a separate process prior to design and the latter is focusing production.
Kaizen is process-oriented, i.e. before results can be improved, processes must be improved as opposed to result-orientation where outcome is all that counts (Imai 1986, p. 16-17)

It is also important to emphasise that the result indeed is of importance, it is rather an assumption that sound processes automatically will end up in good results (Berger 1997). In order to improve a process, it is vital to recognise every separate activity and method in detail. Imai (1986) states that improvement can only be durable in combination with maintaining and improvement of standard performance levels. This implies that a close relation between kaizen and the existence of working standard for all operations.

Working standards within Kaizen is defined as a set of policies, rules, directives and procedures established by management for all major operations which serves as guidelines that enable all employees to perform their jobs successfully (Imai 1986).

To assist the work with continuous improvement of processes and procedures, Deming’s well-known PDCA (Plan-Do-Check-Action) cycle has in many disciplines been adapted as an approach. See figure 3.

Figure 3. The Plan-Do-Check-Action cycle (Imai 1986)
The four steps of the cycle are:

**Plan** - Study the current situation and develop solutions for improvement

**Do**  - Take measures on a trial basis

**Check** - Investigate the effect of changes

**Action** - Standardise on a permanent basis

By targeting the root cause to the problems, rather than correction of the unintended outcome, the aim is placed on permanent improvements (Deming 1982).

The opposite approach, to target improvement by drastic change found in concepts like Business Process Reengineering (BPR) where a larger scope of action is taken. To achieve significant effects, large economical investments are often required wherefore many of these improvements projects have to be planned, sanctioned and controlled by senior management (Bond 1999). It is important to stress that the continuous improvement found in kaizen and the discontinuous approach in BPR are complementary and that focus in both philosophies are placed on improvement of the way of work by studying the process (Walsh 1996).

Bessant et al. (2001) have in a study showed that continuous improvements are realised on to different extents in different companies. A model for describing the different stages of the continuous improvement work in an organisation has been developed, ranging from unstructured continuous improvements to becoming a learning organisation, see Figure 4.

![Figure 4](image-url)
The five different levels of continuous improvement work presented by Bessant et al. (2001) are presented in brief below;

*Unstructured continuous improvement work.*
There is no formal structure for how the company will work with improving performance. Problem that occur are solved at random, depending of the nature of the problem. The personnel do not work with continuous improvements as a process, and use of measurements is limited or none.

*Structured continuous improvement work.*
Formal structure for continuous improving performance is established in the entire company. Problem solving is a structured process, depending of the nature of the problem. The personnel work with continuous improvements as a process, and the personnel are educated in continuous improvement tools. Measurements are in place to facilitate monitoring of progress.

*Goal-oriented continuous improvement work.*
In addition to the previous level, goal and aims for what the continuous improvement initiative are implemented and progress toward these are carefully measured. Continuous improvement work is integrated in every-day work assignments.

*Proactive continuous improvement work.*
In addition to the previous level, anatomy in continuous improvement work is targeted as the personnel is empowered to manage there own work.

*The learning organisation.*
In addition to the previous level, work with continuous improvements is systematic and both identifying and solving problems is a shared activity, from which experiences and knowledge are effectively shared to the entire organisation.

Continuous improvement goals could be summarised in four parts (Wu 2006) as (1) a company-wide focus to improve process performance; (2) a gradual improvement through stepwise problem solving; (3) organisational activities with the involvement of all people in the company from top managers to workers; (4) creating a learning and growing environment.
The influence of organisational learning mechanisms used by quality-focused organisations to support continuous improvement are further investigated by Oliver (2008), the author stresses that a goal of continuous improvement implies the need for learning.

### 2.3 Learning organisation

The learning organisation is knowledge-based organisation continuously defy the way it learns by examine both its internal and external environment (Nonaka and Takeuchi 1995). Garvin and Building (1993) define the learning organisation as ‘is an organisation skilled at creating, acquiring and transferring, knowledge and at modifying its behaviour to reflect new knowledge and insights’. Nevis et al. (1995) refer to a learning organisation as; ‘the capacity or processes within an organisation to maintain or improve performance based on experience’.

To be successful, an organisation’s capacity to learn must exceed the rate of change imposed by the external environment (Buckler 1998). Love et al. (2000) state that for enabling learning on an organisational level and continuous improvement of the organisation and the individuals, there must be processes and structures in place. Newcombe (1999) states that parenting organisations rarely learns from their projects due to the lack of mechanisms to capture knowledge. Herbert (2000) emphases that knowledge is perishable, wherefore it is important for organisations to ensure that continual or preferably continuous learning occurs within the organisation.

Schein (2004) argues that to establish a learning culture, where learning is considered a shared responsibility, reflection and experimentation must be valued and given time and resource. As Schein (2004) puts it:

> [...] the key to learning is to get feedback and to take the time to reflect, analyse, and assimilate the implications of what the feedback has communicated.
Garvin and Building (1993) lists five activities a learning organisation in construction must manage:

2. Experimentation with new approaches.
3. Learning from own experiences and past history.
4. Learning from the experiences and best practices of others.
5. Transferring knowledge quickly and efficiently throughout the organisation.

Argyris and Schön (1978) studied reflective methods of learning and the connection between individual learning and organisational learning. Their research distinguished between two different types of group learning, the single-loop and the double-loop. Single-loop learning occurs when an organisation responds to an alteration in its environment by detecting and correcting errors without changing the organisational norms (Dodgson 1993). Double-loop learning occurs when errors are detected and corrected and leading to a change in an organisations standards or objectives (Argyris and Schön 1978). Bond (1999) states that individual responsibility and incentives do not encourage organisational (double-loop) learning. Argyris (1993) propose the concept of triple-loop learning where focus is placed on dialogue. Triple-loop learning occurs when an organisation realises an opportunity being difficult to grasp or a known problem is still to be solved wherefore the organisation fundamentally starts to re-examine itself and the context it is active in.

Learning occurs either when an organisation manages to reach what was intended or when there is a divergence between intention and outcome, wherefore evaluating the obtained results is important.

Learning can assist an organisation to continuous improve by helping it avoiding making the same mistakes again and improving operations and activities by investigating them to identify how they can be corrected (Lee 1995).

2.4 Performance measurements

The interest in using measurement for gaining further knowledge about a phenomenon is nothing new. Already in 1883 William Thomson held a lecture on the subject of "electrical units of measurement" saying:
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“…I often say that when you can measure what you are speaking about, and express it in numbers, you know something about it; but when you cannot express it in numbers, your knowledge is of a meagre and unsatisfactory kind; it may be the beginning of knowledge, but you have scarcely, in your thoughts, advanced to the stage of science, whatever the matter may be…”

The rationale for conducting performance measurement is to enable systematic learning from experiences and evaluation of gained results. As Helmrich (2001) puts it: 'without collection of data of previous performance, it is impossible to evaluate the outcome of one's performance'. This idea of evaluation of accomplishment is also found in the definition of performance measurement by Neely et al. (1995):

"The process of quantifying the efficiency and effectiveness of action"

Evangelidis (1992) includes the aspects of fulfilment of objectives and strategies to the definition of performance measurement:

“…determining how successful organisations or individuals have been in attending their objectives…”

Performance measurement have in previous research been categorised in various ways. A distinction of the time-orientation for measurements is made by Bashir and Thomson (1999), who distinguish between result and prediction oriented metrics. A result is a measure for a completed system such as design effort or development time whilst a predictor is a metric related to a future result, such as product complexity or design difficulty. Another categorisation regarding time is made by Ghalayini and Noble (1996) differentiating lagging (post-event measurement incapable of affecting the result) from leading indicators (real-time measurement that enables changes during the process). Evidently there are differences in having measurements to report previous performance from having measurements that can serve as a means of control during an ongoing process. Leading measures are recommended to serve as early warnings, identification of latent difficulties and indicate need for further investigation (Costa et al. 2006).

Kagioglou et al. (2001) emphases that organisations using lagging measures, have ability to recognise their past performance, but can not solely looking at the data when trying to determine what contributed to the obtained performance. Therefore, is it recommended to in addition to measuring 'what' the performance was, also identify the
'how' that performance was obtained (ibid). Neely and Bourne (2000) highlights the lack of an improvement process connected to the gathered measurement data, wherefore it is not possible to determine the outcome of improvements made.

Use of data for performance improvement is considered by Bashir and Thomson (1999) as one way possible to avoid severe schedule and cost overruns in construction design projects. Also Chan et al. (2004) states that gathered data can be used to forecast the performance level of a construction project in advance.

Since collection of data can be both expensive and time consuming to manage (Neely et al. 1995), it is of outmost importance that only well-considered measurements are implemented. It is also vital to have a clear objective for the intended use of collected data, since neglecting utilisation of gathered data has been described as "the ultimate management sin", which is still the case in many modern organisations (Neely and Bourne 2000). It is not just a matter of selecting the most suitable measurements, it is also about making a considerable change in decision making processes and learning approaches within an organisation (Costa et al. 2006).

As important as it is for performance measurements to serve as guidance for management decisions (Bassioni et al. 2004), it is as equally essential that management's visions of where the company desires to be, serve as the main input in creation of performance management systems (Kagioglou et al. 2001). By doing this, the performance measurement will serve as an evaluation tool when determining to what extent the result of the process meets the organisation's strategic goals (e.g. Neely et al. 1995; Ghalayini and Noble 1996). Figure 5 illustrates how strategy is related to goals and performance measures.

\begin{figure}
\centering
\includegraphics[width=\textwidth]{strategy_goals_measures.png}
\caption{Deployment of strategy to performance measures (Kagioglou et al. 2001).}
\end{figure}
This opinion is shared by Kaplan and Norton (1996) who argues that the initial use of performance measurement should be to determine the success of implementation of the particular strategy. Other value adding aspect of performance measurement is that it makes benchmarking possible and thus allows a more well-grounded decision making process (Beatham et al. 2004).

Bessant and Francis (1999) states that continuous improvement must be embodied within the company strategy if it is to achieve the desired outcomes. Wu (2006) emphasises the need of a “super structure” not to sub-optimise improvements. In this thesis Lean production is proposed as an overall improvement program.

2.5 Lean Production

The concept of Lean production was established in 1990 when the book “The Machine that Changed the World” by Womack et al. was released. The content of the book is based on conclusions made in an extensive benchmarking study of the car manufacturing industry and performed at Massachusetts Institute of Technology. The study was established to investigate the significant gap in performance between the Japanese and the Western automotive industry, and during a five year period, 52 assembly plants in 14 countries were studied (Womack et al. 1990). The fundamental idea when developing the concept of Lean production was to transfer the Toyota Production System (TPS) to be applicable to Western world settings (Bhasin and Burcher 2006). Womack et al.(1990) put forward lean principles applicable to all various industries, including craft production industry.

Nightingale and Mize (2002) defines lean as a process of elimination waste with the goal of creating value. This will result in less resources used, a more efficient manufacturing process, higher customer satisfaction and in the end, a larger market share (Katayama and Bennett 1996). In 1996, the lean concept was further developed with five supplementary principles for lean production; (1) value, (2) value stream, (3) flow, (4) pull, and (5) perfection (Womack and Jones 1996).
Bhasin and Burcher (2006) presents twelve technical requirements for implementing of Lean production;

1. *Continuous improvement/kaizen.* Continual pursuit of improvements in quality, cost, delivery and design.
2. *Cellular manufacturing.* Group all facilities required to make a product to reduce transport, waiting and process time.
3. *Kanban.* A kanban system needs to be in place.
4. *Single piece flow.* Where products proceed, one complete product at a time without interruptions, backflows or scrap.
5. *Process mapping exercise.* A detailed mapping of the order fulfilment process.
6. *Quick exchange of tools.* To reduce the lead-time and improve flows.
8. *Supplier development.* Develop links with suppliers and working closely with them for mutual benefit.
9. *Supplier base reduction.* Reduce the number of suppliers.
10. *Five S and general visual management.* To reduce the clutter and inefficiency of production and office environment.
11. *Total productive maintenance* (TPM). Improving the reliability, consistency and capacity of machines through maintenance.
12. *Value and the seven wastes.* Value is the capability provided to the customer at the right time at an appropriate price, as defined in each case by the customer.

Lean construction was developed by Koskela (1992), who adjusted the lean production concept to fit construction industry and its prevalent project orientation. Koskela (2000) introduced the Transformation-Flow-Value (TFV) framework arguing that the lean concept by Womack and Jones (1996) was limited to only consider the flow of work within production. According to Koskela, production should be considered as transformations of inputs into outputs where both value and non-value activities flow through the process targeting value for the customer. This framework of TFV has been used in further lean construction research (e.g. Ballard et al. 2001; Bertelsen 2002; Bertelsen and Koskela 2002).
Meiling (2008) considers Lean construction as relevant to industrialised construction but also concludes that the Lean construction community has mainly focused on site-construction and project management.

2.6 Industrialised construction
Höök (2008) uses a production perspective when defining industrialised construction as:

*Production is done in a closed factory environment, where only assembly and some finishing are performed at the construction site, with one owner of a specific process who has a clear goal of selling, production and delivering a product based on repetition in housing design and production.*

Lessing (2006) proposes a more comprehensive view of industrialised construction and defines it as;

*Industrialised house-building is a thoroughly developed building process with a well-suited organization for efficient management, preparation and control of the included activities, flows, resources and results for which highly developed components are used in order to create maximum customer value.*

Lessing (2006) described industrialised construction to possess eight characteristics;

1. Planning and control of the processes
2. Developed technical systems
3. Off-site manufacture of building parts
4. Long-term relations between participants
5. Logistics integrated in the construction process
6. Customer focus
7. Use of information and communication process
8. Systematic performance measurement and re-use of information.

To connect the theoretical framework and previous work of Höök (2008) and Lessing (2006) to the construction design process in industrialised construction, a definition is proposed and applied in this thesis.
The proposed definition of industrialised construction design process is:

A repetitive process with standardized tasks and interfaces, performed with integrated ICT-tools while focusing on the interests of the entire value chain, using a defined building system to translate customer requirements to production parameters for non-unique products in a rigid organisation with long-term improvement focus.

Repetitive process and non-unique products is supported by Höök’s (2008) notion of a ‘product based on repetition in both design and production’. Rigid organisation refers to a staffing not altering from one construction project to another, which coincide with Gibb’s (2001) statement of industrialised construction as something different from traditional site-construction merely moved to a factory environment. The defined building system correspond with Lessing’s (2006) ‘developed technical systems’, implying the need to determine and develop preferable solutions. Consistency in people, products and systems facilitate work with continuous improvements wherefore the long-term improvement focus, and focus on the interests of the entire value chain, inspired from lean theories is included, also supported by Lessing’s (2006) ‘control over activities, flows and resources’. To enable efficient transfer of information to all stakeholders of the value chain, integrated ICT-tools are required. One prerequisite for work with continuous improvements is standardized tasks and interfaces, analogous to what Lessing’s (2006) refer to as ‘a thoroughly developed building process’.

2.7 Model of analysis
The theoretical areas included in this chapter combined with the contextual implications from section 2.6 constitute a framework that supports the problem formulation and aim of the thesis presented in Chapter 1. The theoretical framework has been developed through exploration of the fields of continuous improvement, learning organisation, performance measurements and lean production. The model of analysis is going to be used in Chapter 4 for developing a greater understanding for how work with continuous improvement apply to industrialised construction design process. Figure 6 presents a conceptual representation of the model of analysis.
Figure 6. Model of analysis for this thesis

The model of analysis consists of three important elements for the construction design process, the organisation, the building system and performance measurements. The model has continuous improvements as is main driver, in order to systematically and in small incremental steps improve the construction design process. To avoid sub-optimisation, interaction between the design process organisation and the building system is required. Performance measurements are motivated as a central tool for investigating that the desired effect of the improvement is obtained before the change is accepted on a permanent basis.
3. METHOD

In this chapter the researcher’s background and the research strategy and design are presented, followed by a brief description of the research process. The chapter ends with a discussion of validity and reliability.

3.1. Researcher’s background

A researcher conducting qualitative research can be seen as an instrument for collection and analysis of data in its natural settings wherefore the procedures must be comprehensively presented (Denzin and Lincoln 1994; Merriam 1994; Miles and Huberman 1994). Merriam (1994) emphasises that what makes a case study ‘scientific’ is the researcher’s critical awareness of his/her presence in the studied situation, the choice of data collection techniques and personal influence in analysis and conclusion making. Therefore, the researcher’s background is considered important for understanding the research process at hand.

The researcher’s background is a MSc. in Manufacturing Engineering from Luleå University of Technology, with specialisation on production systems and the interaction between production systems and work organisations. Previous job experiences that are considered relevant are master thesis work at Electrolux Home Products where development and optimisation of an assembly line was made; the role of Quality Technician at Scania Trucks where improvement of the internal quality was focused and finally, a position as Manufacturing Engineer at Stratco targeting improved production volume. In all three cases clear objectives for improvement as well as apparent limitations of the processes were present, in conformity with the underlying research project to this thesis. The experiences of manufacturing and its embedded process-oriented logic are also considered as useful in the industrialised construction context where construction companies adopt ideas from the manufacturing context.

The researcher has throughout the entire research project been involved in the competence centre of Lean Wood Engineering (LWE). LWE is designed as a joint-venture between three Swedish universities (Luleå University of Technology, the Institute of Technology at Linköping University, and Lund Institute of Technology) in collaboration with twelve industrial partners from the wood and wood manufacturing industries as well as the building
sector. The idea behind LWE is to create a competence platform for the integrated development of products, processes and business.

The involvement in LWE has consisted of participation in workshops, conferences and PhD-courses and has enabled the researcher to enhance the general understanding of the studied phenomenon from various views. It has also given the researcher access to further companies working within the studied context. Informal communication with representatives of the studied companies as well as participation at international conferences have resulted in a wider understanding of the studied context, even though it has not emerged in tangible ‘results’.

3.2. Research strategy

Taking a decisive starting point in the overall aim and the three research questions, the research is exclusively based on qualitative methods. Qualitative methods are considered as suitable when studying a phenomenon in its natural context, targeting rich descriptions of the phenomenon and its underlying or ambiguous elements (Miles and Huberman 1994). According to Yin (2003) there are five major research strategies within social science; experiments, surveys, archival analysis, histories and case studies.

All five strategies can be used for exploratory, descriptive or explanatory purposes (Yin 2003). The nature of the research project will determine which of the strategies being most suited. According to Yin (2003) there are three considerations to be made when selecting research strategy;

- The nature of the research questions posed
- The extent of control the investigator has over actual behavioural events
- The degree of focus on contemporary events

In this thesis, two of the included research questions are “how” questions and, which according to Yin (2003) indicates that they are of an explanatory nature and will lead to the use of case studies, histories or experiments as favourable research strategies. The third research question is a “what” question, but has a clear underlying “how” intention and is also of a explanatory nature. The extent of control over behavioural events in this thesis is considered to be low, wherefore experiments are not seen as a potential research strategy. Finally, the focus of the thesis is placed on a contemporary
METHOD

phenomenon, leaving case studies as the best alternative. Merriam (1994) states that case studies can be considered as the best research strategy when the aim of the research is to solve a problem that requires profound understanding of the context and its practice.

3.2.1 CASE STUDY APPROACH
Case studies are regarded as a well-suited research strategy for the underlying research project to this thesis. Since the aim of the thesis is to investigate how the efficiency of the construction design process in industrialised construction can be improved, it is evident that a holistic approach, rich in detail is required. The enhanced understanding of the design process in industrialised construction, can plausibly contribute to development of new knowledge or methods of working.

Flyvbjerg (2006) points out how the familiarity of real life situations and the richness in detail that comes with case studies can assist the researcher in two ways; development of a more balanced view of the studied subject and the researchers personal development. For a researcher that wants to gain competence within a specific area, is the actual contextual-dependent experience crucial to assimilate (Flyvbjerg 2006).

3.3. Research design
Research design is the strategy for connecting research questions together within a research project (Robson 1997). It is vital to determine beforehand how the research project will be carried out, what empirical data to collect, and how analysis and interpretation of the data will be performed. The case study approach can be appropriate when theory building is aimed for in a previously unexplored research field, but also to provide enhanced descriptions of embedded linkage within well established fields (Eisenhardt 1989).

3.3.1 CASE STUDY COMPANY
The main case company is part of a larger company group with four different production plants located in Sweden. The company group had in year 2008 a total turnover of 65.9MEuro and 334 employees in total, of which the division focused in this study had a total turnover of 17.8MEuro and 99 employees. The product variety ranges from movable personnel booths for construction sites, to offices, schools, day-care centres, student dwellings and multi-storey family dwellings. The four divisions all have specialized on different types of products
and the case company focused in this study has its main focus on residential multi-storey buildings.

The construction design department at the main case company consists of seven persons in total, divided into the functionalities of Design Process Manager, Purchase, Structural Design (three persons), Electrical design and HVAC design. Design of ventilation, foundations and non-timber facing are purchased from subcontractors. Construction design for residential buildings for all divisions is performed at the main case company, since the experience and competence levels are considered to be highest there.

The case company was selected based on being a large organisation with long experience from industrialised construction. Also the company's perception of being an industrial company and the explicit interest of working with continuous improvements of the processes made the main case company a good choice for this study.

3.4 Research process

Yin (2003) emphasises the importance of thoroughly describing all research procedures to enable a reader to make up his/her opinion about the reliability and validity of the results.

A schematic representation of the research process is presented in Figure 7.

![Research Process Diagram](image)

*Figure 7. Research process*
The research presented in this thesis consists of three empirical studies that have resulted in three papers, paper I-III. From the three appended papers selected results have been extracted and a cross paper analysis using the model of analysis is made in order to answer the research questions included in the cover paper.

Below is a brief description of the rationale for the three empirical studies performed within this research project and the appended papers they have resulted in.

3.4.1. MULTIPLE CASE STUDY
The first data collection was made in order to understand how the construction design process was organised at the two studied case companies. (In this thesis and in Paper I called company A and company B). The main case company included in section 3.3.2 was one of them. The unit of analysis in the study is the construction design process at each company.

It was also a matter of understanding the contents of a generic construction design process, what activities and tasks it included, and what the flow of information consisted of. The two case companies were selected based on the knowledge that they had chosen to organise their construction design processes somewhat different. One company had a clearer process-orientation, where up to six construction projects in parallel could be handled, while the other worked more sequentially with one or occasionally two projects running at the same time. To what extent the two companies had chosen to keep functions of the construction design process in-house differed. There were 15 interviews made in total, 8 at case company A and 7 at case company B, during the period of March-May 2008. The interviews focused on the current construction design at the two companies, and the respondents were all personnel with different functions within the construction design process.

Data was, besides the interviews, also collected through archival analysis and participating observations at meetings. The archival analysis was mainly focused on time plans for construction design projects and results of previous projects. The meetings were project meetings. The researcher participated in six meetings at company A. Additional data were also collected through an ongoing interview process through e-mail correspondence and phone calls.

The empirical material was then analysed through a Lean perspective, (see table 1 in Paper I). The analysis highlighted several differences between the two case companies that were considered as
results of strategic decisions, wherefore theories of strategies were included. The study resulted in Paper I.

**Paper I:** *Design Process Organisation at Industrial House Builders – A Case Study of Two Timber Housing Companies in Sweden*


**3.4.2 SURVEY**

The rationale for the survey was the difficulty for the main case company to compare different building design projects as well as determine the effects of undertaken improvements efforts. The difficulty derived from the documentation of finished design projects where only total times were recorded. In order to identify alternative ways of measuring the performance of the design process, the proposed research approach was to explore the gap between performance measurement in theory and in practice. A literature study in the research field of performance measurement and performance indicators in construction was made, which resulted in a set of constructs. An interview guide was derived from these constructs and also later used for analysis of the empirical data. In total 10 semi-structured in-depth interviews were made with managers or middle-managers responsible for the design process at the company they represented. The interviews focused on the current use of measurements in the construction design process and were all conducted during the period of February – April 2009.

The ten companies in the survey, consisted of six small to medium-sized industrialised housing companies, meaning they internalise the design, manufacturing and assembly of buildings in one company. Four of the companies were representatives of the construction design departments in the largest construction engineering consultant firms in Sweden. The empirical material was analysed using the set of constructs. (See Table 1, Paper II). The study resulted in Paper II.

**Paper II:** *Housing Design Performance – How is it Measured?*

Written by Erik Söderholm and Helena Johnsson, published in the proceedings of the 25th Annual ARCOM Conference, September 7-9 2009 Nottingham, UK.
3.4.3 SINGLE CASE STUDY

The third empirical study is a single case study where the role of the building system in the building design process is focused. The unit of analysis in this study is the company. The rationale for this study is derived from the experiences the main case company have from working with improving the building design process through standardisation. To increase efficiency and benefit from reoccurring activities and interfaces, the industrialised building companies are interested in finding a more process-oriented way of working than the prevalent project orientation. Since projects are realised within the building system, one way possible is to change the way the building system is used. The study investigates the current use of the building system at the main case company of this thesis.

Data was collected using three different methods; interviews, archival analysis and participating observations at meetings. The interviews were semi-structured in-depth interviews with the Design Process Manager and two of the engineers working at the building design department of the main case company. The interviews were focused on the current way of working in the design process with a special interest in the building system use. Additional data has also been collected through an ongoing interview process through e-mail correspondence and phone calls.

The archival analysis was focused on documentation of the building system and documentation of completed building design projects. The two meetings that were attended were focused on how the building system was going to be documented. The data was analysed through a strategic management perspective, (see Table 1 Paper III). Data for the study was collected during the period of September-December 2009. The study resulted in Paper III.

Paper III: *Building System as a Catalyst for Change from Project to Process Orientation.*

Written by Erik Söderholm and Helena Johnsson, Submitted for publication in Journal of Construction Engineering and Management in February 2010.
3.5 Validity and reliability

Validity in qualitative research is about certifying that the right methods or measurement have been used at the right time, in the right settings and therefore have resulted in correct results. Reliability is about ensuring that the same results and conclusions could be gained if a later investigator would use the same material and methods.

Yin (2003) presents four different methods for ensuring validity and reliability of a research project; construct validity, internal validity, external validity and reliability.

*Construct validity* is reached by using multiple sources of information to triangulate the results of the study and creating a chain of evidence.

*Internal validity* targets the data analysis phase and concerns the investigator’s interference. Previous findings from interviews and other documentary evidence collected in the case study can bias the analysis of the collected data.

*External validity* reflects the possibility to make generalisations of the findings in the case study. In order to determine whether the results of a case study can be generalised, Yin (2003) distinguishes between ‘analytical generalisation’ and ‘statistical generalisation’. In analytical generalisation, previous developed theory is used as a model of analysis by mapping the collected data in order to find similarities and differences. Statistical generalisation on the other hand, is when conclusions about a population are made based on empirical data about a sample of the population. Flyvbjerg (2006) states that it is possible to generalise from single case studies, when the cases are central in the development of a scientific area, but also points out that generalisation sometimes is overrated, as small samples of a population is given too much significance.

*Reliability* is achieved when a researcher can demonstrate that the data collection of a study can be repeated with the same result. Reliability targets to reduce errors and biases in a study (Yin 2003).
3.6 Data collection methods

3.6.1 LITERATURE STUDY
For the research presented in this thesis the following fields of research have been studied:
- Continuous improvement (Kaizen)
- Learning organisations
- Performance measurement
- Lean production

3.6.2 INTERVIEWS
All interviews were semi-structured in-depth interviews where the respondents afterwards had the opportunity to verify the correctness of the interviews, which strengthens the internal validity of the results.

3.6.3 ARCHIVAL ANALYSIS OF DOCUMENTATION
The documentation studied in this research project involves organisation charts, work instructions, checklists for specific work operations, project time plans, plans for improvement of the design process, documentation on previously completed projects and strategic directives from management of the company. Studying the documentation is considered to have strengthened the internal validity as well as the construct validity.

3.6.4 PARTICIPATING OBSERVATION
The participating observations have contributed to the researcher’s knowledge and general understanding of the studied phenomenon, without generating specific documentation. Participation at meetings has enabled the researcher to compare the answers given by the respondents to the real life situation and is considered to have increased the internal validity of the results.
The research questions and data collection methods used in papers I-III are summarised in Table 1.

<table>
<thead>
<tr>
<th>Paper</th>
<th>Research question/aim</th>
<th>Data collection methods</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>“How is the design process organised?”</td>
<td>• Literature study</td>
</tr>
<tr>
<td></td>
<td>“How well do the respective organisations correspond to lean production principles?”</td>
<td>• Interviews</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Archival analysis of documentation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Participating observations</td>
</tr>
<tr>
<td>II</td>
<td>“Which variables currently serve as performance measurements within the construction design process?”</td>
<td>• Literature study</td>
</tr>
<tr>
<td></td>
<td>“How well does the current use of measurements correspond to existing theories for performance measurement?”</td>
<td>• Interviews</td>
</tr>
<tr>
<td>III</td>
<td>Aim: To explore and further analyse the role of the building system when transforming a project-based construction design process into a process-oriented.</td>
<td>• Literature study</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Interviews</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Archival analysis of documentation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Participating observations</td>
</tr>
</tbody>
</table>

3.6.5 CASE STUDY RELIABILITY

The reliability of a study is dependent on the researcher’s objective awareness of how the data collection has been made, and to what degree the researcher has affected the result. High reliability is achieved when data collection can be repeated with the same result. The reliability can also be affected of external causes without the researchers control such as changes in the studied object.

The reliability of this study is for that reason considered as low as the research project was decided to continuously adjust to support the ongoing development of the studied object. Therefore the data collection is believed to be impossible to repeat as the studied object
has changed since the empirical material was collected. Still, some factors contribute to ensure high reliability such as triangulation of data and cooperation with other researchers studying a similar phenomenon at other industrialised construction companies. This is considered to have secured the accuracy of the collected empirical material to a degree where the results are possible to generalise for comparison with theory.
RESULT AND ANALYSIS

4. RESULT AND ANALYSIS

The chapter includes a brief description of the industrialised construction design process followed by the main findings from the appended papers and a cross paper analysis using the model of analysis presented in chapter 2. The empirical data are related to the construction design process in industrialised construction industry.

4.1 Industrialised construction design

The case company claims responsibility for production of the building above the foundation while responsibility for the foundation preferably is handled by a subcontractor, sometimes on a separate contract with the client. If responsibility for the foundation is placed on the case company, this involves additional management activities for the Design Process Manager besides providing the contractor with a foundation plan with information of bearing lines and points loads.

The construction design department is also responsible for scheduling the production and assembly phases. Labelling the building parts is a crucial part of certifying the flow of material throughout the entire process. Coordination of installations such as ventilation, HVAC, and electrical installations is also made by the design department. The building design department works with one or occasionally two projects in parallel. In a designated strive for improved efficiency of the design phase, an organisation with distinct roles and responsibilities have been established. The experience level of the personnel determines what responsibilities each person can have in a project. This specialisation has, according to the Design Process Manager, resulted in reduced average total times of the construction design process.

The construction design process is divided into two distinct phases; building design and volumetric module design. The first phase is commenced with a start-up meeting. Prior to the start-up meeting, the sales department and the in-house architect have developed conceptual solutions that the client has decided to pursue. To enhance the quality of the information delivered as well as ensuring that the project is suitable for the companies building system, a function called “pre-building design” has been established. Capacity shortage in the sales department has prevented the use of the function in practice. The initial step of the construction design process is to generate 3D-models
RESULT AND ANALYSIS

of sections, floor plans and basic plans. These are made using CAD software and are necessary for the external resources responsible for static calculations and HVAC design to initiate their work. Before the project is developed further in detail, the drawings are sent to the client for approval. After the drawings have been approved by the client, and the documentation on statics and building service systems are received, the second phase begins involving detailed development of the components of the building.

There are six different functions in detailed component design: floors, external walls, internal walls, roof, claddings and foundation. The detailed component design generates production drawings and bills of material. Finally there is a completion meeting where the detailed component drawings are delivered to the foremen of the production process.

4.2 Design process organisation

The construction design department at the main case company has an organisation consisting of seven persons in total, divided into the functionalities of Design Process Manager, Purchase, Structural Design (three persons), Electrical design and HVAC design. External resources are used for design of ventilation, foundations and non-timber facing.

The organisation is considered to be rigid in terms of having the same persons involved in every project, but also by the personnel being assigned individual responsibilities for certain activities in the construction design process creating continuity.

The choice of incorporating an organisation with distinct assignments and responsibilities was made targeting improved efficiency in everyday work. Also keeping most functions in-house is a deliberate decision aiming for enhanced control of the entire value chain. For the construction design process, controlling design related tasks is mainly a way of enhancing the information flow and limiting wait. The closeness of functions enables active communication about the progress of the design process where changes can be communicated to all involved parties at once. See Figure 8 for a schematic representation of the design department at the main case company.
Figure 8. Schematic representation of the design department at the main case company.
RESULT AND ANALYSIS

The readiness level of the input from the sales department to the design team has been addressed by creating a function called 'early design'. The purpose of the function is to secure that proposed projects are in accordance with the building system, and that the level of beforehand information is as high as possible. Due to understaffing in both sales and construction design departments, the function of early design is but a product of the drawing board.

In paper I, the construction design processes at two industrialised construction companies, company A and B, are focused. (Company A in this study is the same company labelled the main case company elsewhere). The two companies were selected based on their significantly different choice of organisation model and corporate strategy regarding construction design despite comparable settings on the market. Company A works project-based with on average one project simultaneously, but occasionally two projects have been processed in parallel, while company B has a clear process-based approach handling up to six projects in parallel. See Figure 9 for an illustration of the project and process oriented approaches.
Figure 9. Design process in project and process based work.
Company A, have with an ambition of becoming more efficient developed an organisation with well-defined roles and responsibilities. By utilising check-lists and work instructions the process have become more uniform for every time it is repeated, which has resulted in higher repetitiveness. Company A performs almost all of their functions in-house. Since Company A is part of a larger group of companies, they can utilise additional resources when required. This can be considered as a form of protective capacity. Holding most functions within the company results in the ability to better control the process, but company A has also experienced that when extra capacity has been required, it has been very difficult to find consultants who are familiar with industrialised timber housing.

Company B, on the other hand, has chosen a work organization that enables handling multiple projects in unison within the design process. This allows the company to be more flexible in terms of planning their daily work, but also creates flexibility for the clients as they can affect the products further into the process. The level of standardisation regarding the work process is low at company B, but due to the limited numbers of persons working with a set of specialised tasks, the process can be considered to be carried out uniformly over time.

Company B are highly dependent of external resources, especially in the design process where as much as 50% of the services are outsourced. Since company B have chosen to focus on their core competences and outsource many functions, they are now surrounded by several companies that have a good understanding of their building system and can be utilised if necessary. One negative aspect is decreased control, as well as difficulty to overview the entire status of ongoing processes. See Figure 10 for a schematic representation of the design department at the company B.
Figure 10. Schematic representation of the design department at company B.
RESULT AND ANALYSIS

Planned time for the design process has in both companies a mean value of 20 weeks from the start-up meeting to the production start. Both companies strive to reduce the design process time by 50%. Company A is planning to reinvest the reduced time in standardisation and documentation of the building system, whereas Company B has an intention to focus on enhancing quality throughout the entire process. Activities are carried out sequentially as in traditional site construction for both companies, with documents being the most central information carrier instead of information systems. Company A uses one 3D-CAD software in which all design and drafting are performed, while Company B uses several software and is therefore obliged to produce up to four different model files.

Company A has decided to apply lean principles to the entire company, starting with enhancing the design process and plan to work their way throughout the production flow. Company B has focused on improving the production capacity by investing in automation of the wall production line and has no comprehensive strategy for improving the design process.

The initial step of company A’s work with improving of the construction design process was a thorough investigation of the entire design process. The different activities and tasks were described in detailed and required inputs to and expected deliveries from every activity and task were investigated to provide a comprehensive view of the flow of information. Repetitive activities were differentiated from project-unique ones in order to determine which tasks and activities were suitable for standardisation.

The thoroughness of documentation of the various activities within the process was found to vary significantly since it had been made by different persons without any clear instruction of what it should contain. This documentation currently serves as work instruction for the activities in the construction design process.

It is evident that the construction design team continuously learn from the new experiences that each project provide, but there is currently no systematic way of capturing the knowledge.

There are neither routines nor procedures to facilitate distribution of experiences within the construction design department or the company in general. The knowledge and experiences are therefore
The specialisation in different functionalities that company A have implemented has not only the potential to improve efficiency of the particular task as the deepen understanding, but also render improvement of the product possible. The individual responsibility for specific tasks in the construction design process enables development of improved technical solutions, but understanding and concern for the entire value chain is required to avoid sub-optimisation. This specialisation have improved the efficiency of the construction design process for the case company, but poses a sensitive system as the dependency of specific persons increases.

The specialisation is considered to facilitate a continuous improvement approach as the personnel become experts in selected parts of the construction design process.

One factor obstructing the continuous improvement initiative is the wide variation in the process, originated from offering a broad range of products and being active on several segments of the construction market.

The project structure makes it difficult to find receivers for experience feedback. There is currently no ICT-system that facilitates reuse of information from previous projects.

4.3 Performance measurements

The result in Paper II revealed that time consumption is a measure used by all ten studied companies. The representation of the measure differs in between different companies, where some put it in relation to how well the total time of a project correspond to prediction. One company use a measure to indicate flow by documentation of spent time/square meter building area, while another company measure the amount of time considered as waste. Measures considering quality are usually provided as feedback from production, but this is only documented systematically in two of the studied companies.

Measurement of customer satisfaction is by several of the interviewees not considered to be required since a close interaction
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with the client is required throughout the entire project. One of the interviewees phrases it:

\textit{It is like a dance, and as one notices, it takes two to tango. If we deliver inferior results or ask questions that sticks the client up against the wall (…) we are perceived as a poor partner.}

Collection of data is made easily for all of the studied companies, since employee's working hours are clocked in, usually into an enterprise resource planning (ERP) system, which also compiles the data. All interviewees believe that sufficient amounts of data are currently captured. As one of the interviewees puts it:

\textit{We have information about everything (…) but we are poor in making use of it.}

The major field of application for measurements is currently for prediction of future projects and for analysis on gained results once a project is completed. All companies use data from previous projects in order to estimate time for upcoming projects when scheduling. One difference between the studied companies is to what extent these estimates are based on numerical data or on personal experience.

The interest for continuous improvement of the construction design process and the use of measures for follow-ups on such progress is considered as important by the industrial housing companies. None of the interviewees representing a construction engineering consultant firm shared this opinion. One of the interviewees representing an engineering consultant firm says:

\textit{Follow-ups consume time and cost money. Follow-up on the construction design process does not add any economical value, wherefore it is not done systematically.}

One issue raised, considering the use of measures to improve results is that it can be difficult to determine how different factors in the process have contributed to the final result. One interviewee expresses this by saying:
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The measurement is too general. Just looking at the statistics can be deceptive. You need more background information; there is always an underlying reason for the outcome.

The main case company in this thesis is currently using a measurement of the construction design process expressed as time/square meter produced living area. The performance measurement was constructed by the company themselves and is supposed to indicate the flow rate through the construction process wherefore it is also used in the production phase. The initial idea of implementing a measure was to enable comparison between different projects under the perception that the average times would be comparable.

In the construction design phase it became evident that various construction projects causes fluctuation due to the nature of project. Therefore three different categories of the measurement were implemented to address the disparity in projects; make-to-order building, altered make-to-order building and design-to-order building. Make-to-order buildings and altered make-to-order buildings are based on template buildings while design-to-order buildings is entirely developed based on the generic building system. See Table 2 for average times for the building design work.

Table 2. Average times per square metre for building design work. Based on total times for 22 projects during 2006-2009.

<table>
<thead>
<tr>
<th>Type of project</th>
<th>Average times (hours/m² building area)</th>
</tr>
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<tbody>
<tr>
<td>Make-to-order building</td>
<td>0.40</td>
</tr>
<tr>
<td>Altered make-to-order building</td>
<td>0.42</td>
</tr>
<tr>
<td>Design-to-order building</td>
<td>1.01</td>
</tr>
</tbody>
</table>

The case company has moved from documenting the total times spent on a construction design project, to currently specifying what time have been spent in every step of the process. The resolution of the documented times has incrementally been improved, wherefore it is possible to in detail determine how time for an activity have been spent. See Figure 11 for a schematic representation of how the resolution of the documented time has changed. The documentation has shifted from containing total times spent in the construction design
RESULT AND ANALYSIS

phase, to distinguishing the distribution of time between different activities and finally also included the elements in every activity.

![Diagram](image)

Figure 11. A schematic representation of how the resolution of the documented time has changed at the main case company.

The Design Process Manager at the main case company expresses how prediction and planning of future projects have become more accurate;

> Time planning for future projects has become much easier to do. [...] Previously, only total time was predicted, but now is it possible to look at the detailed time documentation of previous projects, to find comparable objects and better estimate how much time each activity is going to take. [...] The change is evident, and I feel much more confident when creating the time plan for a future construction design project.

Even if there is an explicit intention of working with improvement of the construction design process at the case company, numerical goals or targets is absent. This might be explained by the construction design phase being carried out in form of projects where comparison is difficult to make due to the varying nature of the projects. Therefore it is considered that the used performance measurements are not actually reporting the results of the process, but only the results of the design projects. The Design Process Manager at the main case company puts it;

> There must be goals to strive for. [...] How much must we improve every year?

The current measurements are lagging measures, reporting outcomes of previous projects and do not serve as means of control for the construction design process or enable follow up of undertaken improvement efforts. It is found difficult to determine how different factors in the process have contributed to the final result. The change
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towards measuring smaller parts of the construction design process is considered to increase the possibility to find areas of improvement, as the most time consuming activities can be identified. Another shortcoming of the used measurement is that it only reports the outcome of the design process in terms of time, excluding other important aspects of the result.

The project-orientation makes it difficult to measure the performance of the design process, wherefore comparison between different projects is considered to be difficult. Continuous improvements are found difficult to work with since it requires being properly measured.

The currently used measures are not developed for measuring continuous improvements.

4.4. Building system

In industrialised construction the building system is the core of the construction design process as all projects are carried out using it. The building system is best described as the company’s collected experiences and knowledge in how to realise a construction project. The case company has a building system, consisting of information of successful and preferable solutions from previous projects.

The building system at the main case company must handle the mix of standardised and customised products that is offered. The standardised approach involves a previous attempt to create a number of make-to-order buildings that can be prepared for production with only minor efforts in the building design process. Projects including make-to-order buildings, even with some alterations made, have total times in the design process that are low compared to average total times, see table 2. Projects that involve design-to-order buildings have significantly higher total times than make-to-order projects.

There is a clear difference in opinion, between the sales and the design departments of the degree of fidelity to the building system. The design department argues that the sales department sometimes sells projects that are difficult to realise within the constraints of the building system (note that these constraints are not clear, since projects of diverse types are allowed), while the sales department assert
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themselves as being very strict in selection of possible projects. It is beneficial for the case company to be involved as early as possible in the client’s development of the conceptual idea of the finished building.

This will result in projects that are “generated from” instead of “translated to” the building system.

The documentation of the building system is limited. Even if there is an evident building system, it is previously completed projects that are bearer of the information of successful and preferable solutions. Extensive parts of the building system are only found in the heads of the persons working in the organisation. The most evident part missing is documentation of the rules of the building system. Existing documentation have two main contents; standard solutions (components) and detail specifications (joints). The standard solutions provide detailed descriptions of how components are constructed while the detail specifications explain how the connection between different components is made. There is very little information on how the two interact. Such information is not included in the documentation of the building system, but can occasionally be found in check-lists for activities in detailed component design.

There is also limited documentation regarding the rationale for the chosen solution and which considerations are necessary when using a particular solution. For some parts of the building system there are several possible solutions, but no information available of how and when they should be used. The main case company documents the building system using solely drawings which are stored on a shared directory on the internal company server. In order to create an updated building system, the case company has initiated an effort of documenting what is described as the “current standard of the building system”. A group with representatives from sales, construction design, purchase, production and assembly gather on a regular basis to discuss which solutions are preferable from the perspective of the entire value chain.

For all companies working with a building system core, the balancing of the building system and the resources connected to it against the market needs is essential for survival.
RESULT AND ANALYSIS

The design-to-order strategy is functional in building projects that are unique, but maybe not one-off i.e. some repetition is present. When looking at standardisation, it is more difficult to standardise objects when working with a design-to-order strategy than it is when working with a make-to-order strategy. The case study company has chosen to standardise and document their building system, but has not foreseen the consequences in their own design process. The ‘standard’ is slowly changing over time as more design-to-order projects are performed. The amount of standard solutions increases (in this particular case also without guidelines of when to use a specific solution) and slowly the trust and meaning of a standard solution is lost, since many ‘standards’ apparently exists.

A clear description of the building system would make it possible to communicate the system to actors outside the company itself, thereby gaining from the experience and knowledge general construction engineers possess. However, working with a building system is currently not part of the common engineering knowledge and oftentimes the case study company has experienced that external engineers have trouble to adhere to the system, with violation of the building system and corrupted production economy as a consequence. Some of the uncertainty in the building system is connected to the market position. The case study company is active on several markets; schools, multi-storey buildings, terraced houses etc. and also a wide range of customer, i.e. private developers, municipalities, municipal housing organisations and governmental bodies.

Therefore, the actions of the sales department determine the success of the company.

If a project is sold that are not in compliance with the building system, lower company profit will result. Therefore, the competence of a salesperson at an industrialised builder must be soundly based in production.

To succeed in industrialised construction, the corporate strategy and the production capabilities must be in harmony with the market, otherwise poor performance is at hand.

The main case company is determined to work with continuous improvement of the companies processes. This is of course a good
decision, but it is seemingly not performed in a logical order. The meaning of a corporate strategy is to stand by an idea and carry it through all the way from sales to assembly. Continuous improvements are of no use if the corporate strategy is not followed through; currently the processes are not stable enough to allow continuous improvements.

Still, much of the procedures and processes are the same in different projects even if the product differs.

**Standardisation of processes is therefore a possible way forward, apart from the apparent standardisation of the product itself.**

Standardisation of the processes might also have better payback economically, since much time is spent on coordination and information search in order to reduce uncertainty in the construction design phase. A possible effect of using a well-defined building system is presented in figure 6, Paper III.

**The building system is not considered as the main bearer of information which obstructs the learning effect, as transfer of knowledge is dependent on personal communication.**

The notion that the building system also is in constant change makes the work of documentation difficult

### 4.5. Cross analysis

The model of analysis, introduced in Chapter 2.7, have been used to analyse the empirical material in this thesis in order to support the comprehensive aim of investigating the applicability of continuous improvement to industrialised construction design process. The model of analysis is presented in figure 12 below.
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Figure 12. The model of analysis

Using the framework of different levels of continuous improvement developed by Bessant et al. (2001), (see figure 4 in Chapter 2), the main case company is considered to currently meet the criterion of “unstructured continuous improvement work”. This is mainly motivated by the lack of a formal structure for improvement work and the absence of training for the personnel to work with the methods. The insufficient performance measurements makes comparison between projects difficult and the lack of targets for improvement work makes it unclear what to strive for.

The currently used performance measurement is not considered to support process improvement within industrialised construction. The industrial housing companies need process-oriented measurements that can increase control over performance and enhance information used for decision making. Comparison is the source to learning and improvement, and currently there is no possibility to determine how effective a project is in relation to the building system, wherefore the possibility to take on projects that are not suitable for the case company is imminent which will cause poor performance, see Table 1 Paper III.
The notion of industrial construction companies having to acquire control over the main parts of the supply chain is confirmed by the findings in Paper II and Paper III.

In Paper II, one of the findings indicates a lack of incentive for consultant engineering firms to work with continuous improvements. Being an industrialised construction company in a building industry context makes utilisation of consultants a delicate situation. Since industrialised construction is a fairly new phenomenon and just a small part of the entire industry, there are not many consultants that have experience from working within this discipline. This results in the unfavourable situation where there are a limited numbers of options available, and regardless of previous experiences from these companies, there might not be other alternatives than using one of them again, as they are the only ones familiar with the companies building system. On the other hand, establishment of long term co-operations with consultant firm solves the problem of insufficient understanding of the building system, but can be counterproductive when it comes to continuous improvement of the process. The incentive to enhance the efficiency for a consultant firm which is paid based on the number of hours invoiced can be questionable.

Paper III points out that timely and adequate information at all different stages of the construction design process as vital for the overall performance, leading to the conclusion that until the building system is better defined and more well-known, industrialised construction is best made with in-house resources.

To succeed in industrialised construction, the technology, the production and the business side of the building system must work in synergy with each other, and again the need for a holistic approach in industrialised construction is demonstrated.
5. DISCUSSION AND CONCLUSIONS

This chapter presents a discussion of the applicability of continuous improvements to industrialised construction design based on the analysis made in chapter 4. The research questions in chapter 1 are answered. Generalisation and validity of the presented findings are discussed. Finally suggestions for future work are proposed.

5.1. Industrialised construction design

The construction design phase has proven to be the most time-consuming part of the construction process at most industrialised construction companies in Sweden. Meiling (2008) points out the notion of every construction design project being seen as new and unique, as one explanation to why the use of experiences from previous projects is limited. Höök (2006) identified a potential for industrialised construction companies to utilise experience from projects and incorporate it into standardised processes. Lessing (2006) and Höök (2008) have in previous research within the industrialised construction industry in Sweden, identified design and production preparation as sub-areas where further development is needed.

The rationale of industrialised construction requires both controlled products and controlled production processes where consideration of the entire value chain is taken in every task and activity. The industrialised construction design process plays a key role as it maintains the product and decides the production conditions. Translating customer requirements to production parameters and presenting them on drawings is the main objective of the construction design process, but scheduling the production and assembly phases are also responsibilities of the construction design department.

The products of industrialised construction are realised within a building system, which is based on experiences the construction company have made in previous construction projects. Even if the building system is company-specific all industrial construction companies have in common that the building systems are central and important both in everyday work and in strategic development of the company. The development of a building system is not so much a technical quest as it is organisational and resource dependent.

Continuous improvement of a building system encompasses solving issues with material suppliers, production techniques and design
routines. Standardisation of processes is the goal to obtain a stable environment for continuous improvements. Treating continuous improvement of the building system as a technical question only is impossible and result in bad overall performance.

Therefore this thesis includes an investigation of the applicability of continuous improvement to the industrialised construction industry.

5.2. Design process organisation

The results of the study show that having a rigid organisation, with the same personnel from one project to another, is favourable when working with continuous improvements. The main case company have chosen to assign personal responsibility for different tasks and activities to increase efficiency in everyday work. Keeping most of the functions in-house is another decision made to create stable processes. This has made the personnel develop process skills and gain technical expertise, wherefore areas of improvement can be identified and possible solutions proposed. The main case company’s approach to thoroughly investigate the entire design process and differentiate repetitive activities from project-unique ones in pursuit of standardisation is aligned with the strategy for continuous improvement work proposed by Imai (1986). Using the classification by Bessant et al. (2001) the main company meets the criteria for ‘unstructured continuous improvement work’. The lack of a formal structure for problem solving, the absence of education in continuous improvement tools and the limited use of measurements, prevents a higher level.

The study in Paper I shows that the degree of outsourcing can differ in industrialised construction. It is not a matter of owning all functionalities and resources, but about having control over them. A fragmented organisation demands a more developed building documentation system for information transfer.

Currently there is no system or routines for how knowledge and experience from previous projects can be captured, stored and shared, a finding previously concluded by Borgbrant (2003) and Forsberg and Saukkoriipi (2007). In combination with the personnel being experts in a limited area of the process, the construction design process becomes a sensitive system as the dependence on specific individuals increases. To facilitate work with continuous improvements of the construction design process, commitment of the personnel is required, also pointed out by Wu (2006).
5.3. **Performance measurement**

The result of the study in paper II confirms that the “iron-triangle” (i.e. time, quality and cost) still is prevalent as performance measurement in the construction sector, also see Hapanova and Al-Jibouri (2009).

The main case company is currently using a measure of the construction design process performance expressed as time/square meter produced building area. This performance measurement was constructed to measure the flow rate through the construction process. The measure was initially created to enable comparison between different projects as the average times were believed to be comparable.

The main case company realised that variation in construction projects caused fluctuations that render comparison impossible. Therefore three different categories of the measure were implemented; make-to-order buildings, altered make-to-order buildings and design-to-order buildings.

The main case company has also shifted from measuring total times of construction projects to measuring elements of specific activities, which is considered to assist in identifying improvement opportunities. Still, the used measure is a lagging measure meaning it is only a representation of the outcome of previous project and not a tool for control of the construction design process. Another shortcoming of lagging measurements, Kagioglou (2001) and Neely and Bourne (2000), is the inability to determine how different factors have contributed to the total result.

The current measure is not considered to support continuous improvement work, as comparison across all project-types is difficult. It is also impossible to determine the effect of improvement initiatives by only studying the measure.

5.4. **Building system**

In industrialised construction the building system is the core of the construction design process as all projects are realised in it. The building system at the main case company must handle both standardised and customised products.

There is a clear difference in opinion, between the sales and the design departments of the degree of fidelity to the building system, but it is agreed as beneficial to be involved already when the client’s develop a conceptual design of a building. This will result in projects that are “generated from” instead of “translated to” the building system.
The documentation of the building system, which can be seen as the company’s standard, is limited. Currently, previously completed projects are bearers of the information of successful and preferable solutions. Existing documentation have two main contents; standard solutions (components) and detail specifications (joints). The standard solutions provide detailed descriptions of how components are constructed while the detail specifications explain how the connection between different components is made. There is very little information on how the two interact. There is also a lack of descriptions of alternate solutions and why these are considered inferior to the current standard. Product development is therefore difficult since the documentation is an “as-is” picture, no history or version control.

Documentation of the “current standard of the building system” has been initiated, wherefore a group with representatives from sales, construction design, purchase, production and assembly gather regularly to discuss preferable solutions from a value chain perspective.

The case study company has chosen to standardise and document their building system, but has realised that the ‘standard’ is slowly changing over time as more design-to-order projects are performed.

A clear description of the building system would make it possible to communicate the system to actors outside the company itself, thereby gaining from the experience and knowledge general construction engineers possess. Some of the uncertainty in the building system is connected to the market position. The case study company is active on several markets; schools, multi-storey buildings, terraced houses etc. and also work with a wide range of clients, such as private developers, municipalities, municipal housing organisations and governmental bodies. The perceived uncertainty by clients and the company itself obstruct the use of the building system as a bearer of information which obstructs the learning effect and somewhat work with continuous improvement.
5.5. Conclusions

Much of the procedures and processes are the same in different projects even if the product differs. Standardisation of processes is therefore a possible way forward, apart from the apparent standardisation of the product itself. Standardisation of the processes might also have better payback economically, since much time is spent on coordination and information search in order to reduce uncertainty in the construction design phase. A possible effect of using a well-defined building system is presented in figure 13.

![Figure 13. Possible reduction in initial uncertainty when using a building system.](image)

One road forward can be use of continuous improvement as a tool for performance improvements. In this study, the applicability of continuous improvements to the industrialised construction design process has been investigated and it is found to be relevant with minor restrictions.

The rigid organisation with control over main parts of the value chain, possess the ability to standardise both processes and procedures. The consistency in personnel allows development of process skills and technical expertise, wherefore areas of improvement can be identified.
and possible solutions proposed. The building system is a potential bearer of information, but demands a high level of documentation.

Actions to be made to improve the applicability of continuous improvements involved implementation of formal structure for problem solving, education in continuous improvement tools and enhanced performance measurements. The measurements must support comparison across all project-types and enable evaluation of the effect of improvement initiatives. Also systems and routines of how knowledge and experience from previous projects can be captured, stored and shared are necessary.

A conclusion made is the need for the industrialised construction companies to be involved as early as possible in the clients’ development of a conceptual building. The sales department plays a vital role in ensuring that construction projects can be “generated from” instead of “translated to” the building system, wherefore the sales department determine the success of the company. It becomes even more evident taking the implication of industrial construction needed to operate at almost full capacity for profitability into account.

The research included in this thesis identify timely and adequate information at all different stages of the design process as crucial for the overall performance, which confirms that industrial construction companies have to acquire control over main parts of the supply chain.

Another conclusion is that success in industrialised construction requires that the corporate strategy and the production capabilities are in harmony with the market, otherwise poor performance is at hand. One essential aspect is recognising the strategic importance of having and constantly developing a building system.

5.6. Methodology and validity discussion

Already the choice of research strategies and data collection methods involves limitation to what results that can be obtained and which conclusion that can be made. For the research included in this thesis, case study research was considered a suitable research strategy. Section 3.2 and 3.3 provides a description of how the case study was accomplished.
The possibility to make generalisation from case studies is dependent on the selection of cases, as well as thorough descriptions of how the studies were performed and the background and pre-understanding of the researcher. The background of the researcher and the choice of case company are described in section 3.1 and 3.3.1.

As in all quantitative research, the use of multiple sources of evidence can ensure construct validity. In this study several sources of information has been used to triangulate the results.

External validity on the other hand refers to the possibility to make generalisations of the findings in the case study. The findings and conclusion presented in this thesis are considered to be limited to only apply to industrial construction companies in Sweden, with similar settings and being active on the same markets as the main case company.

Reliability refers to the possibility to repeat a data collection and receiving the same results. The reliability of this study is considered to be low since the underlying research project continuously have adapted to the development of the studied company, wherefore repeating the data collection is considered impossible.

5.7. Future research

The research in this thesis regarding the applicability of continuous improvements in industrialised construction design process has highlighted a number of areas that are of interest for future research.

One of the obstacles to overcome to facilitate work with continuous improvement is the lack of process-oriented performance measurements. There is a need to develop measurements that can assist the industrialised construction companies to predict, control and evaluate the performance of the processes, not only the outcomes of construction projects.

There are also questions left to solve regarding how experiences and knowledge best can be captured, stored and shared in a systematic manner.

The research included in this thesis also display the need to further explore the connection between market strategies and operational strategies in order to ensure that the holistic view promoted in industrialised construction is taken into account.
REFERENCES


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Design Process Organisation
at Industrial
House Builders: a Case Study of Two Timber
Housing Companies in Sweden

Authors:
Gustav Jansson
Erik Söderholm
Helena Johnsson

(The paper has been edited to fit the format of the thesis, but the contents remain the same).
DESIGN PROCESS ORGANISATION AT INDUSTRIAL HOUSE BUILDERS: A CASE STUDY OF TWO TIMBER HOUSING COMPANIES IN SWEDEN

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In industrial construction companies the design process tends to be the bottleneck for further streamlining of the entire manufacturing process. The demands posed on this particular design process are diverse; should feed the production process with data, should satisfy the client with documentation and should document the project for experience feedback. Further complications arise from the internal notion of being a manufacturing company opposed to the external view of the company being a traditional building firm. In this work, the design process at two industrial builders was studied in-depth. The two companies have chosen opposing strategies for their design departments; one have specialised functions where all projects pass and the other have more general designers who work in parallel with similar tasks. With the support from lean production theory, the consequences of these two strategies on succeeding with design of industrial built houses are analysed. The results show that increased specialisation is beneficial in daily work, but can pose a sensitive design process if key competences suddenly vanish.

Keywords: corporate strategy, design process, housing, industrialisation, prefabrication.

INTRODUCTION

Industrialised housing is a growing market segment on the Swedish construction market with a market share of approximately 15 % (Höök 2008). The degree of prefabrication differs; single wall elements can be prefabricated as well as entire volume modules complete with interior claddings and equipment. When larger portions of the building process are harnessed by the same company, possibilities for streamlining the process arise. Later years have seen an increasing interest in lean construction (Koskela 1992). Industrialised housing was described by Lessing (2006) as having 8 characteristics; experience feedback, process control, developed technical systems, off-site manufacture, long-term relations, integrated logistics, customer focus and use of ICT tools. For industrialised house builders, the internal processes are best described by lean production, while the external processes belong to the lean construction framework (Höök 2008). In this study, two volume element producers are focused. They internalise the design, manufacturing and assembly processes normally carried out by different companies in an ordinary building process. Therefore a customer focus has to be placed on clients, subsequent activities as well as end customers. A common problem for the two companies is that the design process is the bottleneck for increasing volume in production. The aim of this paper is to analyse

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the design process at two industrialised house builders in Sweden through a lean production perspective.

**METHODOLOGY**

The decisive starting-point for the data collection were our research questions, “How is the design process organised?” and “How well do the respective organisations correspond to lean production principles? The unit of analysis was defined as the design process at two (specific) companies within industrialised housing in Sweden. Despite comparable settings on the market for both companies, the choice of strategy for organising the design process differs.

When choosing research design, case study research (CSR) was considered a suitable alternative, since the questions are “how” questions, we have little control over the events and focus a contemporary phenomenon in a real-life context (Yin 2003). In studies of how two companies in timber housing execute their daily work there are very little control over events for the investigators. The focus of this study is on a contemporary phenomenon within a real-life context. This is a multiple case study (of two companies) with a single unit of analysis (the design process) (Yin 2003).

Data has been collected using three different methods; interviews, archival analysis and participating observations at meetings. The interviews were all semi-structured in-depth interviews with 15 persons in total, 8 at Company A and 7 at Company B. (Functions of the respondents can be found in figs 1 and 2). Focus of the interviews was placed on the current way of working in the design process. The archival analysis was mainly focused on documentation regarding time scheduling for design projects. All in all, we participated in six meetings at Company A and seven meetings at Company B. Through the study, additional data has continuously been collected through an ongoing interview process. Identification of the need for additional data was made in a comparison between the two cases, but also when theoretical knowledge increases. At both companies there were designated contact persons for correspondence. Data from different sources were triangulated to increase the validity in the case. This was a well needed method since the models for organising the design process and associated activities were not directly observable at any of the two studied companies.

The material was then analysed through a Lean perspective, based on table 1. During this analysis, we realised that all diversities and similarities were consequences of choices made by the companies. Therefore it was essential for the study to find a theory capable of explaining differences in strategies. Mintzberg and Waters (1985) theory about deliberate and emergent strategies appeared to be usable.

**Case study companies**

Company A is a timber volume element builder specialised in products ranging from simple small booths, to office buildings, schools and multi-family dwellings. Houses built by Company A are mainly of four stories. Main customers are one large contractor in most of the multi-dwelling projects. The customisation degree is high due to several different factories. Company A has 300 employees allocated at four production facilities and an annual turnover of 42 MEuro.

Company B is also a timber volume element builder with specialisation in student lodgings, hotels, multi-family dwellings and senior dwellings. Houses built by Company B are mainly of four stories. Main customers are co-operative building societies, real-estate trustees and student associations. The
customisation/standardisation degree is high within projects. Company B has 135 employees located at one production site and an annual turnover of 42 MEuro.

LEAN THINKING

The aim for perfection is the foundation of lean production. Central to the success of the lean production approach is the involvement of personnel, who are encouraged to see mistakes as possible points of improvement. The basic idea is simple – reduce unnecessary operations (waste) with uncomplicated methods to promote increased flow targeted at creating customer value. The notion that work organisation is directly coupled to the manufacturing strategy might be most pronounced in lean production (Womack and Jones 2003). Lean production is one of the manufacturing principles that have been transferred to the construction industry i.e. lean construction (Koskela 1992).

In Lean production the concept of value is central together with concept of waste. Everything not adding value is considered to be waste. Womack and Jones (2003) states that the aim is increased value in every process step. Value is defined as the price customers are willing to pay for a product (Womack and Jones 2003). Value can also be research and development generating value for strategically important choices in a long-term perspective (Höök 2008). Organisationally and strategically, value stream is central for the management in Lean Thinking. Resources, such as information, people, systems and work strategies, are necessary in a holistic perspective to achieve a better value stream in the design process (Rother and Shook 2003). Pull is the mechanism to deliver exactly what the customers need, at the time it is required (Womack and Jones 2003). Björnfot (2006) summarises the approach of Lean Thinking in eleven principles for flow in construction, which are related to increasing the transparency and output flexibility with values from the process. Planning and management are important in the process for flow with a reduction of non-value activities, variability, cycle times and unnecessary steps.

Lean Design is summarised by Jørgensen (2006) for publications about design in construction through the late nineties until 2006. The design management is focused in the publications, where theories about conversion, flow and value from Lean Construction are presented and Lean theories are based on the five criteria of Lean Thinking i.e. Brookfields characteristics of management for Lean Design (Jørgensen 2006). See table 1.

For the prefabrication of timber housing it is important to see how different approaches to Lean can be applied. Design for industrial timber housing can not be fully described, neither using Lean Production nor Lean Construction (Höök 2008). Koskela (1992) emphasises the importance of the “connecting parts” in the construction process, where people and information links create transformation, which is the major difference compared to Lean production theory (Höök 2008). Both customers and actors in the design process must be analysed in view of the construction context. Within industrial manufacturing of houses the reuse of information in the design process is low and the actual design work is made with site construction methods. The project related approach in Lean Construction can be necessary for design activities related to value generation.
Table 1. Model for evaluation, based on the five lean principles

<table>
<thead>
<tr>
<th>Conceptualisation in construction (Björnfot 2006)</th>
<th>Characteristics for lean design (Brookfield 2004)</th>
<th>Evaluation criteria for obtaining a lean design process</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Value</td>
<td>Identify value from the customer’s point of view</td>
<td>1. Are customers defined?</td>
</tr>
<tr>
<td>Define the customer</td>
<td></td>
<td>1.2 Is customer value defined?</td>
</tr>
<tr>
<td>Define what is value for customer</td>
<td>Understanding the value streams by which value is delivered for the whole design process.</td>
<td>1.3 Is value for the design team defined?</td>
</tr>
<tr>
<td>Define what is value to the delivery team</td>
<td></td>
<td>1.4 How is value transparent in information and drawings?</td>
</tr>
<tr>
<td>Define how value is specified by products</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Value stream</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Define all resources for production</td>
<td>Achieving synchronous flow within work processes as waste is removed.</td>
<td>2. Are all resources for the design process defined?</td>
</tr>
<tr>
<td>Define all activities required for production</td>
<td></td>
<td>2.2 Are all activities in the design process defined?</td>
</tr>
<tr>
<td>Standardise current practice.</td>
<td></td>
<td>2.3 Are the processes standardised?</td>
</tr>
<tr>
<td>Define and locate key component suppliers.</td>
<td></td>
<td>2.4 Are key information suppliers defined?</td>
</tr>
<tr>
<td>3. Flow</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Identify non-value adding activities (waste).</td>
<td>Achieving pull so that no information is delivered until it is needed.</td>
<td>3. Are non-value adding activities (waste) identified?</td>
</tr>
<tr>
<td>Remove or reduce the influence of waste as it is observed.</td>
<td></td>
<td>3.2 Is the influence of waste removed or reduced?</td>
</tr>
<tr>
<td>Identify key performance indicators.</td>
<td></td>
<td>3.3 Are key performance indicators identified?</td>
</tr>
<tr>
<td>Measure performance.</td>
<td></td>
<td>3.4 Is performance measured?</td>
</tr>
<tr>
<td>4. Pull</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Keep the production system flexible to customer requirements.</td>
<td></td>
<td>4. Are design systems flexible to customer requirements?</td>
</tr>
<tr>
<td>Keep the production system adaptable to future customer requirements.</td>
<td></td>
<td>4.2 Is the design system adaptable to future customer requirements?</td>
</tr>
<tr>
<td>Exercise a conscious effort at shortening lead and cycle times.</td>
<td></td>
<td>4.3 Are efforts in shortening lead and cycle times exercised?</td>
</tr>
<tr>
<td>Perform work at the last responsible moment.</td>
<td></td>
<td>4.4 Is work performed in the last responsible moment?</td>
</tr>
<tr>
<td>5. Perfection</td>
<td>Perfection - recognising that improvement needs to be constantly pursued.</td>
<td>5. Are design systems and routines transparent to all stakeholders?</td>
</tr>
<tr>
<td>Keep the production system transparent for all involved stakeholders.</td>
<td></td>
<td>5.2 Is experience from completed projects captured and implemented?</td>
</tr>
<tr>
<td>Capture and implement experience from completed projects.</td>
<td></td>
<td>5.3 Are efforts made to improve value for customers?</td>
</tr>
<tr>
<td>Exercise a conscious effort at improving value for customers.</td>
<td></td>
<td>5.4 Are efforts made at improving the execution of work?</td>
</tr>
<tr>
<td>Exercise a conscious effort at improving the execution of work.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Lean Construction theory as well as Lean Design, mainly focuses on traditional onsite construction with customer value at a project level (Lessing 2006). Strategical choices in the organisation of the design process at two industrial timber housing companies are compared against the criterions in Lean Production and Lean Thinking, Table 1. Björnfot (2006) states, that Lean philosophy can be applied to construction when a mixture of the five principles, represented in column 1, table 1, is at hand. In column 2, the characteristics for Lean Design according to Brookfield (2004) are presented. In column 3, the Lean criteria for evaluating design processes are presented, based on the theory characteristics in columns 1 and 2.

DIVERSES IN STRATEGIES

Strategy has been conceived in terms of what leaders of organisations ‘plan’ to do in the future. As long as there has been an interest in strategies within organisations, there has also been curiosity about the relationship between what is planned and what is actually done. Labelling these two phenomena in terms of strategy, Mintzberg and Waters (1985) make a distinction between deliberate strategies – realised as intended,
and emergent strategies—patterns or consistencies realised despite, or in the absence of, intentions. Deliberate and emergent strategies are by Mintzberg and Waters (1985) described as poles of a continuum along where all real-world strategies could be expected to fall.

Mintzberg and Waters (1985) propose eight types of strategies: 1. Planned strategy: Leaders formulate their intentions as precisely as possible and then strive for implementation i.e. translation into collective action. 2. Entrepreneurial strategy: One person in control of an organisation and imposes his or her vision of direction on it. Since vision only provides a general sense of direction, there are room for adaptation of other visions within the organisation. 3. Ideological strategy: When members of an organisation share a vision and pursue it strongly it becomes an ideological strategy. 4. Umbrella strategy: When leaders only have partial control over actors in an organisation, they implement a vision but have to convince others to pursue it. 5. Process strategy: Leaders exercise influence on strategy indirectly, for example by controlling the staffing of the organisation, and thereby determining who gets to influence strategy. 6. Unconnected strategy: If a part of an organisation is loosely coupled to the rest, it might be able to realise its own pattern in its stream of action and therefore its own strategy. 7. Consensus strategy: No need for central direction or control is required since different actors naturally converge on the same theme so it becomes pervasive in the organisation. 8. Imposed strategy: The organisation is forced into a pattern in its stream of actions of the environment, regardless of the presence of central control.

**CASE STUDY**

Company A has a total of eleven employees in the design department, divided into the functionalities of Design Process Manager, Purchase, Structural designers (six persons), Electrical drafting and HVAC drafting (two persons), see figure 1. A role called early planning has been established to enhance the readiness level of the input from the sales department to the design team. Sub-contractors are utilised for static calculations, foundation drafting and ventilation drafting.

Company B has a total of seven employees in the design department, divided into the functionalities of Design Process Manager, Project Manager, Design Manager, Purchase, Coordinator for sub-contractors, Building design and Structural design, see figure 2. Sub-contractors are utilised for HVAC, foundation and ventilation drafting.

![Figure 1: Company A organisation chart](image-url)
Company A works project-based with normally just one project simultaneously, but occasionally two projects have been processed in parallel, see figure 3. At Company A, planning of projects is based on time in total for the entire group. The Design Process Manager distributes tasks and assignments to the members of the team, which they work with throughout the project.

Company B has a clear process-based approach with a capacity of up to six projects in parallel, see figure 3. Due to parallel project, Company B plans every included part of the design process in detail. Every team member can be described as a specialist within a certain area i.e. 2D CAD-drawing, design managing, volume construction.

Planned time for the design process has in both companies a mean value of 20 weeks from the start-up meeting to the production start. Both companies strive to reduce the design process time by 50%. Company A is planning to reinvest the reduced time in standardisation of the building system, whereas Company B has an intention to focus on enhancing quality throughout the entire process. Activities are carried out sequentially as in traditional site construction for both companies, with documents being the most central information carrier instead of information systems. Company A uses one 3D-CAD software in which all design and drafting are performed, while Company B uses several software and is therefore obliged to produce up to four different model files.

For visualisation of the design process, both companies use visual planning. Company A uses live documents on a file server with ongoing projects’ status, while Company B uses a whiteboard where the current status of thirty-two activities/documents is indicated by different colours.

Company A has recently decided to apply lean principles to the entire company, starting with enhancing the design process and plan to work their way throughout the production flow. Company B has focused on improving the production capacity by
Design process organisation

investing in automation of the wall production line and has no comprehensive strategy for improving the design process. Lean principles are only used in minor sections in the design process at Company B.

ANALYSIS

Analysis of the design process at the two companies was done based on the lean perspective criteria in column 3, table 1. The analysis gives an indication on how well the design processes correspond to lean principles. Numbers in brackets indicate the corresponding criterion in table 1.

Value: Company A has their focus on the product in an object-oriented organisation. Value for the customer is the possibility of having better quality and controlled technical solutions due to an individual owner for each task in the design process. Customer value is a pronounced focus at Company B where the strategy is to take market shares in a new market area. The process-oriented organisation creates value for the customer, through flexibility in handling parallel projects in the design process (1.1, 1.2). Weekly meetings and sharing of visual information creates value for the design team itself. Waste is identified in the communication with sub-contractors e.g. time delays for checking drawings, information about project specific conditions and drafting revisions (1.3, 1.4)

Value stream: The value stream can be defined in resources and activities for conversion in Lean Design, where Company A uses fewer interfaces in the process but more interfaces in the product e.g. between wall and openings, wall blocks and inner roof. Company B has to deal with many interfaces in the process, to promote the value stream, such as software file formats, individual task status and individual work standards, but remains a comprehensive view on the whole product. Standardisation in the design process is done on a deeper level for Company A with standardisation for tasks (2.1, 2.2, 2.3). Company B has maintained its process focus and has not put effort in the work of standardising sub-tasks.

Flow: The flow of information and drawings in the design process is low within both companies. Company A uses 3D-CAD with central models for projects but with limited connections to production compared to Company B. Up to four different CAD models can be produced for each project at Company B, which decreases the flow. The range of software is the result of the implementation of automated machinery in the production. Nail robots use control files created by the CAD-system (DDS), which increases the flow. Paper drawings are used at both companies (3.1). The use of sub-contractors in the design process sometimes causes time delays for information sharing. In-house resources can be seen as supporting flow (3.1, 3.2, 3.3, 3.4).

Pull: Production time is shorter than time for design, which fulfil the pull criteria in-house at both companies. However, overall rate in design is too slow, 20 weeks in average compared to 4 weeks of production in the factory. Company A has streamlined their design work to obtain a production with higher delivery accuracy. Company B on the other hand, has started with streamlining their production and is now taking measures to convert design to flow better (4.3, 4.4).

Perfection: By the use of visual planning both companies have transparency in their design process status. Templates, checklists and quality routines for following up projects are present, but not common in the design process (5.1, 5.2). However, the common goal for the design team is not perfection of the entire process, since sub-
optimisation is common. Standardisation of certain sub-tasks is not the same as
optimising the entire design process.

The analysis of the organisation in the two cases shows that the focus on different key
factors for the entire manufacturing process affects the appearance of the activities and
tasks in the design process. Company A’s approach of implementing early design and
allocating personal component responsibility (e.g. walls and floors), creates an
apparent project focus which generates value in the product, both for internal
(production) and external customers. Company B’s strategy is reliant on customer
requirements where the flexibility in the process-oriented organisation provides value
for the customers. Having parallel design processes allows clients to influence the
selection of components like alarm systems, kitchen appliances, etc. further into the
design process. Decisions have to be structured with several object-specific deadlines
through the process to use the advantage of flexibility.

Company A is part of a larger corporation where strategically important decisions and
directives are emanated from central leadership. Therefore the concept of planned
strategy, according to Mintzberg and Waters (1985), appears to be the best
comparable alternative. According to Liker (2004) there is an evident need for leaders
to live the philosophy of Lean and spread it to employee (top-down implementation).
Company A has recently decided to adopt lean principles on the company.

Company B is a family business with a strong leader and facilitating Mintzberg and
Waters (1985) terminology, the concept of entrepreneurial strategy seems to apply the
best.

Since the leader’s vision is personal, it can also be changed completely. This allows
the organisation to quickly respond to changes in the environment, thus can be
considered to enable implementation of new strategies. Company B has not adopted
lean principles at a company level, but there are actors in the organisation influenced
of Lean Thinking. Based on the evaluation of strategy types, neither of the companies
appears to have strategies especially facilitating or obstructing implementation of a
lean concept.

Standardisation is a principal strategy to create efficiency in the design process and
the authors perceive different conditions at the studied cases. Company A have clearly
defined their organisation with distinct assignments and responsibilities.
Implementing the function of early design has given Company A the ability to ensure
that potential projects are compatible with the building system as well as enhancing
the quality of data entering the design process.

Company B has an organisation with explicit responsibilities, but activities are not
divided into assignments for specific persons. The process-oriented approach creates
expertise in performing the work task, but may not contribute to improvement of the
product since focus is placed merely on one activity. Working with several different
ICT tools, results in a non favourable situation regarding managing versions of files
and documents. Based on these findings the authors believe that standardisation of the
building system might be more straightforward to execute at Company A.

Using lean production principles to improve the design process in industrialised
housing is considered to be insufficient due to the complex situation of being
manufacturers in a constructional context. Neither concepts nor theories founded in
manufacturing settings or traditional site construction are completely valid for these
particular circumstances. Lean production is by Crowley (1998) described as “unsuitable to small-scale production of non-standardise or customised products”.

Jørgensen (2006) states that defining value for end customer in construction is complicated since end customer for a building can be several different individuals distributed over extensive periods of time. Furthermore, it cannot be taken for granted that an increased productivity necessarily serve the interests of the end customer (Green 1999). Neither can flow be considered to be as essential in everyday work as in theory, since the design process is not sequential as production generally is.

In order to differentiate which activities being repetitive (and beneficial for standardisation, i.e. cross sections, fire documentation and room description) from project-unique activities (“handled individually”, i.e. balcony solutions, elevator and stairwell) the design process must be fractionised and analysed.

Former research in this field has primarily discussed the influence of lean production on regular site construction (Green 1999; Naim 2003). Since Koskela (1992) introduced Lean Construction, focus has shifted towards investigation of its applicability (also on site construction). Therefore it has been of extra interest to perform this case study with lean production perspective in the industrialised housing context.

This study states that lean production alone, is not a sufficient tool when improving the design process in industrialised housing. Future work needs to combine lean production and lean construction to support industrialised housing.

CONCLUSIONS

Industrial housing companies have to acquire control over the process to benefit fully from owning the entire system and therefore being able to improve it. Using only lean production principles for improving the design process is not sufficient.

It is therefore needed for the industrialised timber housing companies to:

- Thoroughly investigate all included tasks within the design process in order to differentiate repetitive and project-unique activities. By doing this, tasks suitable for standardisation can be identified.
- Standardise procedures for repetitive work in order to better utilise resources as well as ensuring that knowledge of the product and the building system is captured within the system itself, not only in persons working in it.
- Make use of well-suited ICT support to automate interfaces. Industrialised housebuilders have reoccurring interfaces every time the design process is repeated. However, they may not necessarily have a repetitive design in itself.

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Housing Design Performance: How Is It Measured?

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(The paper has been edited to fit the format of the thesis, but the contents remain the same).
HOUSING DESIGN PERFORMANCE: HOW IS IT MEASURED?

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Industrialisation involves reoccurring tasks and interfaces, which enables companies to work with continuous improvements of the process. In order to determine the effects of undertaken measures as well as enhance the manageability of the process, it is important to find measurements for effectiveness and efficiency of the construction design process. The aim of this paper is to serve as a gap analysis regarding the differences between current practice and the characteristics of performance measurement found in literature. This study is based on interviews with middle-managers at six industrial housing companies and four construction engineering consultant firms in Sweden, in order to explore the current methods of performance measuring in the construction design phase. The result shows that the studied companies currently have a limited use of measures and that the present measurements do not serve as a means of control for the design process or enable follow ups of undertaken improvements. For extended control and continuous improvement of the design process additional methods for measuring are required.

Keywords: construction design process, design management, off-site production, performance measurement.

INTRODUCTION

The Swedish construction sector has in previous studies been reported to be inefficient and slow in adjusting to changes, in addition in urgent need of improved product quality and financial result (SOU 2000; SOU 2002). There are also reports indicating that Swedish construction companies generally overlook the opportunity to assimilate knowledge from previous projects with a systematic approach (Borgbrant 2003; Forsberg and Saukkoriipi 2007). Industrialisation of the construction process has been mentioned as one road forward in pursuit of improvements, wherefore companies have changed focus to prefabricated products with various degrees of specialisation (Lessing et al. 2005). This change in strategy transforms the construction companies from object-oriented, on-site construction firms, into process-oriented off-site manufacturers with increased control of the value chain (Höök 2008).

Being in charge of the entire value chain, from sales to completion on the construction site, in combination with a design organisation not altering amongst projects, enables these companies to work with continuous improvements of their processes and reoccurring interfaces (Jansson et al. 2008).

Still there is a lack of well defined, easy to implement sets of measurements that support work with productivity improvement. Therefore the construction industry is currently relying on the ‘iron triangle’, i.e. time, cost and quality (Haponava and Al-

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Jibouri (2009). In addition, a recent study, initiated by the Swedish government, concludes that some of the flaws in the Swedish building sector, might erupt from insufficient procedures for making research results available to construction companies (Stadskontoret 2009). Derived from the statements above, the following set of research questions has been developed:

Which variables currently serve as performance measurements within the construction design process?

How well does the current use of measurements correspond to existing theories for performance measurement?

To be able to answer the questions a set of constructs was developed using literature on performance measurement. The proposed constructs are explored in practice by evaluating ten companies within the Swedish housing trade. To identify any possible differences in practice between different segments of the industry, six of the companies are industrialised housing companies whilst four companies are "conventional" construction engineering firms.

The aim of this study is to serve as a gap analysis regarding the differences between current practice and the characteristics of performance measurement found in literature. This will lead to future development of performance measurements which is believed to be valuable to the construction industry.

This paper focuses exclusively on performance measurement within the Swedish construction industry, additionally demarcated to performance in the design stages of the construction process at six industrial housing companies and four construction engineering consultant firms.

METHOD

By examining the research fields of performance measurements and performance indicators in construction the authors have gained knowledge within this field. (Kaplan and Norton 1992; Neely et al. 1995; Kagioglou et al. 2001; Bassioni et al. 2004; Beatham et al. 2004; Chan et al. 2004; Costa et al. 2006; Haponava and Al-Jibouri 2009) are among the sources that have been studied. By combining the presented findings a set of constructs for evaluating the current use of performance measurement within housing design in the Swedish construction sector was developed. This study compares the current practice with what is suggested in literature, and gives an indication of how the studied companies are measuring their performance.

Data has been collected through semi-structured in-depth interviews with 10 persons in total. Focus of the interviews was placed on the current use of measurements in the construction design process. All interviewees were managers or middle-managers with responsibility for the design process at their company.

Questions were asked about both the nature and the use of measures and the interviewees’ opinions regarding use of measurements for management of the construction design process were captured. To what extent measures were used to improve the design process and how connection between corporate strategy and objectives in used performance measurements was realised, were aspects of extra interest.

Examples of questions asked: How is the measurement collected and analysed? What are considered to be the strengths and weaknesses with the used measure? Can the
Housing design performance

measure be used as means of control for the design process? It is possible to use the measurement through different stages of a project? How is the measure aligned to strategies and objectives? How is data from previous projects re-used in new ones? Can the used measures be used for benchmarking?

Company A to F are small to medium-sized industrial housing companies, meaning they internalise the design, manufacturing and assembly normally carried out by several different companies. Industrialised housing holds a share of approximately 15% of the Swedish construction market (Höök 2008). Company G to J are all among the largest construction engineering consultant firms in Sweden and all interviewees were representatives for construction design sector of the companies.

PERFORMANCE MEASUREMENT

The interest in using measurement for gaining further knowledge about a phenomenon is nothing new. Already in 1883 William Thomson held a lecture on the subject of "electrical units of measurement" saying:

"...I often say that when you can measure what you are speaking about, and express it in numbers, you know something about it; but when you cannot express it in numbers, your knowledge is of a meagre and unsatisfactory kind; it may be the beginning of knowledge, but you have scarcely, in your thoughts, advanced to the stage of science, whatever the matter may be..."

The rationale for conducting performance measurement is to enable systematic learning from experiences and evaluation of gained results. As Helmrich (2001) puts it: 'without collection of data of previous performance, it is impossible to evaluate the outcome of one's performance'. This idea of evaluation of accomplishment is also found in the definition of performance measurement by Neely et al. (1995):

"The process of quantifying the efficiency and effectiveness of action"

Evangelidis (1992) includes the aspects of fulfilment of objectives and strategies to the definition of performance measurement:

"...determining how successful organisations or individuals have been in attending their objectives..."

Performance measurement has in previous research been categorised in various ways. A distinction of the time-orientation for measurements is made by Bashir and Thomson (1999), who distinguish between result and prediction oriented metrics. A result is a measure for a completed system such as design effort or development time whilst a predictor is a metric related to a future result, such as product complexity or design difficulty. Another categorisation regarding time is made by Ghalayini and Noble (1996) differentiating lagging (post-event measurement incapable of affecting the result) from leading indicators (real-time measurement that enables changes during the process). Evidently there are differences in having measurements to report previous performance from having measurements that can serve as a means of control during an ongoing process. Leading measures are recommended to serve as early warnings, identification of latent difficulties and indicate need for further investigation (Costa et al. 2006).

Kagioglou et al. (2001) emphases that organisations using lagging measures have ability to recognise their past performance but can not solely look at the data when trying to determine what contributed to the obtained performance. Therefore, is it recommended to, in addition to measuring 'what' the performance was, also identify
the 'how' that performance was obtained (ibid). Neely and Bourne (2000) highlight the lack of an improvement process connected to the gathered measurement data, wherefore it is not possible to determine the outcome of improvements made.

Robinson et al. (2005) divide performance measurement in terms of being either financial or non-financial measurements. The main pitfall for financial measures is that they are lagging metrics, representations of outcomes and decisions made in the past and therefore not of much use in improving current performance (Ghalayini & Noble 1996). Use of data for performance improvement is considered by Bashir and Thomson (1999) as one way possible to avoid severe schedule and cost overruns in construction design projects. Also Chan et al. (2004) state that gathered data can be used to forecast the performance level of a construction project in advance.

Since collection of data can be both expensive and time consuming to manage (Neely et al. 1995), it is of outmost importance that only well-considered measurements are implemented. It is also vital to have a clear objective for the intended use of collected data, since neglecting utilisation of gathered data has been described as "the ultimate management sin", which is still the case in many modern organisations (Neely and Bourne 2000). It is not just a matter of selecting the most suitable measurements, it is also about making a considerable change in decision making processes and learning approaches within an organisation (Costa et al. 2006).

As important as it is for performance measurements to serve as guidance for management decisions (Bassioni et al. 2004), it is as equally essential that management’s visions of where the company desires to be, serve as the main input in creation of performance management systems (Kagioglou et al. 2001). By doing this, the performance measurement will serve as an evaluation tool when determining to what extent the result of the process meets the organisation's strategic goals. Figure 1 illustrates how strategy is related to goals and performance measures.

Figure 1: Deployment of strategy to performance measures (Kagioglou et al. 2001).

This opinion is shared by Kaplan and Norton (1996) who argue that the initial use of performance measurement should be to determine the success of implementation of the particular strategy. Another value adding aspect of performance measurement is that it makes benchmarking possible and thus allows a more well-grounded decision making process (Beatham et al. 2004).

**MEASUREMENTS IN PRACTICE**

Time consumption is a measure used by all studied companies. The way that the measure is represented differs in between different companies, where some put it in relation to how well the total time of a project correspond to prediction. Others, like
company B use a measure of spent time/square meter building area, whilst company D utilise a measure for time waste. Measures considering quality are usually provided as feedback from production, but only two companies document this systematically. Answering a question regarding measurement of customer satisfaction, several of the interviewees answered that it is not considered to be needed since a close interaction with the client is required throughout the entire project. One of the interviewees phrases it:

*It is like a dance, and as one notices, it takes two to tango. If we deliver inferior results or ask questions that sticks the client up against the wall (...) we are perceived as a poor partner.*

Collection of data is made easily for all of the studied companies, since employees’ working hours are clocked in, usually into an enterprise resource planning (ERP) system, which also compiles the data. All interviewees believe that sufficient amounts of data are currently captured. As one of the interviewees puts it:

*We have information about everything (...) but we are poor in making use of it.*

The major field of application for measurements is currently for prediction of future projects and for analysis on gained results once a project is completed. All companies use data from previous projects in order to estimate time for upcoming projects when scheduling. One difference between the studied companies is to what extent these estimates are based on numerical data or on personal experience. Only two of the companies have measurements that allow collection and analysis during a running project. It is considered difficult to determine to what extent a project is completed, during it is running, and the measures of time and cost can only indicate how much of the allocated resources (i.e. time and money) that have been used.

None of the interviewed companies have a measurement that facilitates benchmarking. Several interviewees expressed their concern over identifying a numerical measurement to facilitate comparison of construction design performance between different companies, regardless of project- or company-unique aspects. All interviewees still express that they consider a possibility to make such a comparison as fruitful. One manager expresses the need for benchmarking by saying:

*It is actually our raison d’être being determine.*

Many of the interviewees encourage an extended openness regarding work routines and procedures, and the ability to learn from each other.

The interest for continuous improvement of the construction design process, and the use of measures for follow-ups on such progress is considered important by almost all of the industrial housing companies. None of the interviewees representing a construction engineering consultant firm shared this opinion. One of the interviewees says:

*Follow-ups consume time and cost money. Follow-up on the construction design process does not add any economical value, wherefore it is not done systematically.*

One issue raised, considering the use of measures to improve results is that it can be difficult to determine how different factors in the process have contributed to the final result. One interviewee expresses this by saying:

*The measurement is too general. Just looking at the statistics can be deceptive. You need more background information; there is always an underlying reason for the outcome.*

Questions regarding what objectives and strategies the company have, resulted in widely different answers. Among the different objectives were “reduce the time for
construction design by 50 percent”, “become more industrialised” and "become the client's number one choice” mentioned. The interviewees representing company A and F stated that their company do not have any explicit objective or strategy for development of their construction design process.

CONSTRUCTS FOR ANALYSIS

In order to make a critical analysis of the current usage of performance measurement in the studied companies, two constructs were created:

10. Use of measurement.

Table 1: Analysis of studied companies' current use of performance measurement

<table>
<thead>
<tr>
<th>Conditions</th>
<th>A</th>
<th>B</th>
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<tr>
<td>1.1 Scope of measurement is easy to understand</td>
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<td>1.2 Enables use throughout different stages of project</td>
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<td>1.3 Alignment to company strategies</td>
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<td>1.4 Enables benchmarking</td>
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<td>2.1 Easy or automated data collection</td>
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<td>2.2 Support decision-making</td>
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<td>2.3 Serve as a mean of control during an on-going project</td>
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<td>2.4 Support process improvement</td>
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</table>

Nature of measurement

1.1 The majority of the studied companies are considered to meet this criterion of easy understandable measurement to a high extent. The two companies that are considered to meet this criterion to a normal degree have, besides collecting data on spent time, constructed their own measurements which result in a normal correspondence to the condition. Measures of quality and customer satisfaction were all considered to be easy for understanding.

1.2 Only a few of the companies have measurements that allow collection and analysis during a running project. For this reason measures are only used in estimating the outcomes of coming projects and for evaluation of completed projects. Most of the
companies use measurement for prediction of outcomes and for analysis on gained results once a project is completed.

1.3 Even if all studied companies use time as their main factor for evaluation of performance, only company B and E have explicit objectives or strategies that include a quantity of time. This results in low correspondence to the condition of having measures aligned to company strategies and objectives. This is seen as an indication of the deficient use of measures for evaluating progress towards a desired future state for the construction design process.

1.4 None of the interviewed companies have a measurement that is found suitable for benchmarking. Since all used measures are regarded as being influenced by project- or company-unique factors, comparison with other companies is not possible.

**Use of measurement**

2.1 Collection of data is considered to be done easily for all of the studied companies, since employees' working hours are clocked in. Company B needs supplementary data besides time for calculation of their measurement, also added that the calculation is not automated, resulting in a lower correspondence to the condition in comparison to the other companies.

2.2 Most companies use data from previous projects in order to estimate time for upcoming projects when scheduling. One difference in between the studied companies is to what extent these estimates are based on numerical data or on personal experience. Company A is considered to correspond poorly to this condition by not using numerical data.

2.3 The lagging measurements prevent the companies to use them as means of control for the construction design process. Company D is the only company who has a daily follow-up on their performance measurement, and therefore can act swiftly on deviations on the process.

2.4 Having total consumed time as the major measurement for evaluation of project outcome does not provide the companies with identification of improvement opportunities. The measurement is rather used to display the result after the project is completed. With a plethora of factors differentiating one project from another, a measurement of total time spent will not facilitate the opportunity to identify potential improvement options. Company B is considered to meet the condition for identification of improvement opportunities to a high extent since measuring divided parts of the process increases the opportunity to identify potential areas of improvement. Company D can through their measurement on time waste work for obtaining a more efficient process, and is also considered to correspond to the condition to a high extent.

**Connections between constructs**

All companies are using measures that are easy to understand as well as also effortless to collect (condition 1.1 and 2.1). Also clear is that the prime use of measures is to enhance accuracy in estimation of future projects (resulting in ordinary correspondence to condition 1.2) not for enhancement of process control during ongoing projects (condition 2.3).

Comparison between different clusters of companies, points out a prominent disparity in the level of interest for construction design process improvement. None of the studied construction engineering firms, (company G to J), have in the interviews given
any indication of having incentives of working with continuous improvement of the
design process, which is clearly seen in condition 2.4.

DISCUSSION
The Swedish construction industry has in several reports been described as inefficient
and in need of improvement. One possible way to monitor performance and follow up
undertaken improvement initiatives is through use of performance measurements. This
paper focuses firstly on the current use of performance measurements in the
construction design process, and secondly, on how well the used measurements
correspond to previous research made within this field.

The survey shows that the main variable for measuring construction design
performance is time. How the measure is expressed and represented in the studied
companies differs. Some of the studied companies measure the total amounts of time
spent in a project, while others compare actual time spent with estimated time for the
project. Quality is also of interest for the studied companies, but little effort is made in
documentation on this subject. This confirms that the “iron triangle” (cost, time and
quality) still is the prevalent measurement of performance within the construction
sector, also reported by Haponava and Al-Jibouri (2009).

The constructs created in order to analyse how well the current use of measures
corresponds to existing theories for performance measurement highlight that the
existing measures are easy to understand as well as collect, but are solely lagging
measures which do not serve as means of control for the construction design process.
It is also determined that the used measurements are not satisfactory in terms of
monitoring process improvements, since they only report the outcome of projects, not
how different factors have affected the result, a finding also reported by Kagioglou
(2001) and Neely and Bourne (2000). The project-orientated measures also render
difficulties in comparison between projects since all projects are considered to be
unique and one-of-a-kind due to various reasons. This results in an inability to
evaluate progressive performance which consequently excludes comparison with other
companies wherefore benchmarking is considered to be impracticable for all the
studied companies. Another finding is the weak correlation between objectives and
strategies for the construction design process and the measures used.

The study also indicates a variation in interest in continuous improvement of the
construction design process between industrial companies and construction
engineering consultant firms. This might be explained by different initiatives for
improvement among the studied companies: the industrialised housing companies
(company A to F) are foremost focused on ensuring availability of correct production
documentation for the production system, where the companies’ product and customer
value is created. The construction engineering consultant firms (company G to J) on
the other hand, have the construction design as their final product and are therefore
mainly interested in maximising profit from the number of hours invoiced in a project.
It is therefore considered that the industrialised housing companies should have a
greater interest in relating performance measurement to the company objectives
regarding design process improvement.

Proposed future research is development of process performance measurements. The
predominant project-focus on performance measurement, in practice as well as in
literature, is not sufficient for use within industrial housing, where improvement of
processes is of main interest. This gap has also been identified by Haponava and Al-
Jibouri (2009). Also suggestions of how excessive information of previous performance should be captured in order to facilitate experience feedback and lead to improve decision making is necessary.

**CONCLUSIONS**

The current used performance measurements (i.e. time, money and quality) are not considered to be sufficient in terms of supporting process improvement within industrialised housing. The current used measurements are lagging measures, reporting outcomes of previous projects and do not serve as means of control for the construction design process or enable follow up of undertaken improvement. The industrial housing companies are therefore in need of process-oriented measurements in order to increase control over their performance and enhance data used for decision making.

**ACKNOWLEDGEMENTS**

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**REFERENCES**


Building System as a Catalyst for Change from Project to Process Orientation

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(The paper has been edited to fit the format of the thesis, but the contents remain the same).

Building System as a Catalyst for Change from Project to Process Orientation

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ABSTRACT

In industrialised construction and in most modern off-site production methods, a building system is at the core of business. The building system offers strategic advantages as repetition and experience feedback may be worked with efficiently. However, it is difficult to realise these benefits (Höök 2008). The building system focuses on the production process rather than on the product or on the project.

The aim of this paper is to explore the role of the building system when a project-based construction design process is transformed into a process-oriented one in an industrialised construction company active on the housing market. The investigation is based on a case study of one industrialised construction company in Sweden. Data has been collected through semi-structured interviews, participation in meetings and on documentation of the project. The building system as a bearer of process-oriented methods is discussed. The tension between standardisation and flexibility is analysed.

The results show that companies engaged in industrialised construction must maintain one production strategy to avoid parallel organisation capabilities which leads to lower profit. The building system is identified as a strategic asset for industrialised construction companies. It is central when balancing the market position against the internal resources in the company. The production strategies presented by Winch (2003) are discussed and it is shown that balancing two production strategies leads to bad performance for the studied company.

Keywords: building system, technical platform, industrialised construction, housing, off-site methods
INTRODUCTION

The Swedish construction sector has been characterised as inefficient and slow in adjusting to change, and in need of improved product quality and financial results (SOU 2002; Ds 2004). Similar concerns have been raised in the UK, where the Egan Report (1998) reached similar conclusions. Both in Sweden and the UK, industrialisation (or the use of modern off-site production methods) of the construction process has been mentioned as one way forward in the pursuit of improvements (Lessing 2006; Goodier and Gibb 2007). In Sweden the most frequently used term for this new way of working is “industrialised construction” whereas “off-site production” is used in the UK. In the US the production of modular or manufactured homes is part of the same branch. Both the construction of housing and industrial buildings can be included, but focus has been mostly on housing.

Höök (2008) states that moving construction off-site transforms the construction companies from object-oriented on-site construction companies, into process-oriented off-site manufacturers with extended control of the value chain. One reason for this transformation is that industrialised construction is a process different from traditional site-based construction that is merely transferred into a factory. Here, on-site practices and culture are challenged to reflect manufacturing culture (Gibb 2001). Earlier research on industrialised construction mainly has focused on how “Lean Production” and “Lean Thinking” can be adopted to improve the production system and the supply chain (Naim and Barlow 2003; Höök 2008; Höök and Stehn 2008). There is currently little insight by researchers and practitioners into competitive strategies for housing companies (Green et al. 2008).

One question that remains unanswered is how an industrialised construction company’s objective of improved efficiency can be reconciled with the client’s requirement of receiving a unique one-of-a-kind product. Winch et al. (1998) describe construction as a realisation of “concepts” where clients use the construction company’s resources, both internal and external, to realise their products. Realisation of a construction project means gradual reduction of uncertainty both for the client and the manufacturer, (Winch 2001). Realisation of a construction project transforms customer requirements from design parameters into production process parameters (Suh 1990).

An industrialised construction company relies on the use of a “building system” for the above transformation. A building system is a commonly agreed company-specific set of rules for realising a building through combining prefabricated components. The rules are geometrical, methodical or organisational. The building system plays many roles in a company. Firstly, it is the backbone of production. All equipment is developed and purchased with the
goal of efficiently producing building system components. Investment costs are heavy, which often results in a non-flexible production system in terms of product variants. Secondly, the building system offers repetition in design. CAD templates are easy to programme, which results in fast drafting of building system parts. Thirdly, the building system offers a base for working with quality tools in production and with experience feedback in the entire company. The building system provides stability which enables industrialisation.

If projects are to be realised within a building system, one step towards process orientation is to change the way the building system is used. A highly standardised building system might be beneficial in terms of optimising the design and production process, but would possibly result in difficulties in finding customers for the products. On the other hand, offering excessive levels of flexibility means that continuous improvement of the internal processes is difficult and contradicts the rationale of industrialised construction where economies of scale are sought. In this paper, “flexibility” is considered to be the consciously allowed degree of uncertainty in a system to increase value for the client. “Standardisation” is considered to be the opposite of flexibility with less possibility for clients to affect the product.

The threats to the building system are the market forces in construction which demand variation and in-depth involvement from clients and architects. This threat causes the requirements placed on a building system to fluctuate to such an extent that the built-in flexibility in both design and production is assailed. Finally, lower company profit is a risk.

The aim of this paper is to explore and analyse the role of the building system when transforming a project-based construction design firm into a process-oriented one. The strategic importance of the building system is identified. This is done by focusing on the design process and its interfaces upstream and downstream at one industrialised construction company in Sweden.

INDUSTRY CONTEXT

During the last fifteen years the industrialised timber housing branch within the Swedish construction industry has gained ground. When Sweden became a member of the European Union in 1994, the building regulations were adjusted accordingly and the new building codes allowed the erection of multi-storey timber frame buildings, which previously had not been permitted in Sweden. Timber housing companies are often family-owned, smaller firms with a long-term strategy, which seemingly fit industrialisation well. We have seen failed initiatives with both steel frame (Open House, specialised company) and concrete elements (NCC, general contractor). These initiatives have gained much attention, but they seem to have taken too big leaps too fast, in
combination with impatient managements that wanted immediate results. Most of the timber building systems are produced by family-owned companies where development took place in small steps, giving the organisation the opportunity to mature gradually. Market demands on housing were low during the 1990s, making it possible to develop in small steps and at a reasonable pace. The companies that steered in the direction of industrialisation were only five to ten in number. When the market recovered in the year 2000 and the demand for multi-storey timber housing exploded, demand exceeded production capacity. This resulted in a need for development but as the companies were usually small they did not have the financial means to effectuate this development forward by themselves. Today industrialised housing accounts for about 15% of the Swedish housing construction market (Höök 2008) and there are two predominant structural systems, Fig. 1:

- **Volume prefabrication** – Light timber frames industrially assembled to volumetric modules
- **Element prefabrication** – The frame is built by flat elements, either with a massive timber core or a timber frame

![Figure 1. (a) Volumetric modules (b) Flat massive timber elements.](image-url)
Fig. 2 gives an overview of the production process at an industrialised housing company.

Figure 2. Production process using a volumetric module structural system, Meiling (2008).

Since the new EU building code became effective the timber industry has taken two development steps forward. The first step implied the verification of working solutions where the timber material showed that it fulfilled the functional requirements in the code. In the second step, the manufacturing process, the transportation technique and supplier relations were developed. These prefabricated units today have a high level of added value and may be transported over long distances. Current challenges for the companies in this market segment are long-term sustainability, life-cycle economy and high-rise building technology. There is no market in Sweden for modular homes of the kind on the US market, since all buildings need to comply with the same national building code. Instead, prefabricated units are employed to produce standard apartment buildings in competition with all other available structural solutions such as steel and concrete building systems.
THEORY

Strategic focus on business environment or internal resources

Junnonen (1998) concludes that the rapid change in the construction industry’s business environment has made strategic thinking more important for construction companies. Construction firms have mainly focused on effectiveness in separate projects and not on long-term strategies (Price and Newson 2003). On a business level, two factors govern success: (Porter 1981; Porter 1985) put forward the market position and (Mintzberg 1979; Wernerfelt 1984; Peteraf 1993; Hamel and Prahalad 1994) pointed to the importance of the internal resources. Hamel and Prahalad (1994) stressed the connection between organisation alignment and market success.

To fit the market needs, companies can adopt three basic business strategies; a low-cost strategy, a differentiation strategy and a focus strategy, which can be combined with any of the two former (Porter 1985). To avoid culminating in ‘strategic dissonance’ (Brown 2003), which is a mismatch between the company and its market, or between the intended strategy and the company’s capabilities, it is important for a company to revise its strategic formation at intervals. Hayes and Pisano (1996) claim that achieving long-term success requires differentiation from competitors in terms of offering something perceived as valuable and unique to the clients, such as low cost, innovative products, high reliability or flexibility.

From a resource-based point of view, the company’s internal resources are as important as the market position (Flanagan et al. 2007). Resources can be of six categories: financial, physical, human, technological, reputation, and organisational (Grant 1991). Resources are both tangible and intangible (ibid). The resource-based view on core competence is valid in construction (De Haan et al. 2002). The capabilities needed to combine and make use of resources fall into three categories: market, innovation, and production (Rangone 1999), all of which were investigated by De Haan et al. (2002). Using internal resources to capitalise on core competence differs from fitting into a market niche and is referred to as market stretch, (Hamel and Prahalad 1994; Johnson et al. 2008). It is the combination of market fit and market stretch that forms a successful strategy for a firm. The firm-specific resources or strategic assets should meet the criteria of being valuable, rare, imperfect imitable, non-substitutable and imperfectly mobile and gain their strategic advantage through being difficult for competitors to imitate (Barney 1991). Construction faces the complication that projects are one-time by their nature, have temporary organisations and high costs for storage which seldom leads to economies of scale (Hillebrandt 1984). However, the industrialised construction sector offers another setting, where
Strategies exist at different levels in a firm; the corporate strategy differs from the business strategy, which in turn can have a production strategy (Junnonen 1998). All sub-strategies must be linked together to make the firm move forward, which is a managerial task. Smaller firms can have a “single business unit organisation”, which means that the corporate strategy and the business strategy overlap more than in larger corporations. Cheah and Garvin (2004) define business strategy as an organisation’s focus on the products and services that it could offer, should offer or is targeting to offer, while operational strategy is focused on implementation and execution of the processes that transforms various inputs to products and services. In industrialised construction this can be seen as a choice of emphasising either a product orientation or a process orientation. A product orientation results in a product, or a range of products that suit the target market of the organisation (Porter 1985), which the company chooses to organise itself around. In order to gain efficiency the products are standardised to varying degrees. A process orientation on the other hand, will instead emphasise execution of the processes required for creating a service or a product and are more focused on improving internal competence and abilities (Hamel and Prahalad 1994). Efficiency is gained through systematisation and standardisation of processes and procedures.

The design process links business strategy to operational strategy

Irrespective of the business strategy chosen, it is in the construction design process that the client’s conceptual requirements are transformed into a more tangible product proposal. Gibb (2001) states that design decisions generally are required earlier in industrialised construction than in conventional construction, and that critical information is needed as early as possible in the process. It is therefore of interest to consider to what degree the client is allowed to participate in the design process. Winch (2003) argues that most classifications of production strategies have a tendency to reduce the importance of the design process in production. He developed a categorisation that defines where the client enters the production information flow. The production information flow is by Winch (2003) defined as “the flow of information required for the production of the product from initial concept through to delivery to the customer”.

repetition and stable organisations are available, which give economies of scale at least at the component level (Gibb 2001).

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Winch (2003) presents four generic production strategies:

A Concept-to-order; the client enters at the start of the information flow and is also the one initiating production.

B Design-to-order; the company has a basic product concept but a significant amount of engineering design work is undertaken for the particular client.

C Make-to-order; the company has a fully detailed design that can be configured to suit a client’s particular requirements or alternatively, no additional design work is done.

D Make-to-forecast; the company produces products for stock that are sold after they have been manufactured.

The four strategies A-D include various degrees of uncertainty in the product design process where strategy A has the highest degree of uncertainty and strategy D the lowest. Winch (2001) referred to the project process as ‘a process of the progressive reduction of uncertainty through time’, where a project at inception involves high levels of uncertainty which is continually reduced until all required information is gathered in the final product, figure 3.

![Figure 3. The project process as a progressive reduction of uncertainty over time, Winch et al.(1998).](image)

Uncertainty has also been addressed in terms of the difficulties of task performance (Baccarini 1996; Tatikonda and Rosenthal 2000). The more uncertain the task is, the greater the quantity and quality of information needed to generate the knowledge necessary to complete the task. Tatikonda and Rosenthal (2000) also argues that there are two different sources of uncertainty.
within product development; technology novelty/complexity and project complexity. Technology novelty is defined as ‘the newness, to the development organization, of the technologies employed’ while project complexity is defined as ‘the nature, quantity and magnitude of organisational subtasks interactions posed by the project’ (Tatikonda and Rosenthal 2000). The concept of product development is relevant in industrialised construction where the prevalent one-off, unique project approach often results in a continuous product development process integrated in ongoing production. The more unfamiliar the stakeholders are with the contents of a project, the more vital it is that the entire project team agree on critical information at an early stage (Gibb 2001).

**Development of the building system regulates the level of uncertainty**

One way to regulate the level of uncertainty in the design process in industrialised construction is to determine the degree of flexibility that the building system is to contain. The term “flexibility” has in previous research been considered a complicated one to define, one reason for this is the many interpretations of the term (Paslawski 2008). In this paper, flexibility is considered to be the degree of uncertainty that is consciously allowed in a system to increase value for the client. Standardisation is considered to be the opposite of flexibility with no possibility for clients to affect the product.

Standardisation of products and components which in other industries enabled continuous improvements has proven difficult to realise in the construction industry as a result of the predominant one-off, unique project approach (Gibb 2001). It is important to emphasise that in industrialised construction, uniformity in the process is sought, not uniformity in the products. Gibb (2001) reports construction projects where standardisation of procedures led to increased confidence in the outcome of the project as stakeholders gained increased familiarity with the processes. In industrialised construction, there is a constant struggle between flexibility and standardisation and often the manufacturers find themselves somewhere in the continuous shift from flexible to standardised solutions. A solution proposed by Lennartsson (2009) among others is to apply modularisation to address the need for standardised products which have high flexibility.

**Product offer**

Nord (2008) states that the “product offer” is the exchange between the market position dimension and the operative platform dimension. Focusing on the operative platform, which is the building system, construction companies can address the market using product offers according to three production strategies:
make-to-order, design-to-order and concept-to-order products. Make-to-forecast is never used in construction; it involves investment costs to store and transport entire buildings that are too heavy. Components can be produced using this strategy. In industrialised construction, the concept-to-order strategy is seldom employed, since it implies that the building system is redesigned every time a new building project is started. A combination of strategies is possible. Companies that offer make-to-order products compete utilising the efficiency of the organisation, and companies offering design-to-order products compete by their flexibility meeting the customer requirements, while companies producing with both types of strategies must be both efficient and flexible (Filley and Aldag 1980). The parts of a company focused on efficiency such as technology, labour and production processes, are inconsistent with those parts required to achieve flexibility, making it difficult for companies to combine the two strategies (Filley and Aldag 1980; Fiegenbaum and Karnani 1991). Tushman and O’Reilly (1999) propose that a company can only produce both standardised and flexible outputs efficiently if production is performed in physically separated facilities, having different organisational structures, different skills in labour etc; in other words two separated divisions with pure configurations.

**ANALYSIS FRAMEWORK**

The analysis framework combines the level of uncertainty within the four different production strategies presented by Winch (2003) with the amounts and quality of information needed in the design process in industrialised construction, fig. 4. The aim of the framework is to demonstrate how different strategic approaches for the building system result in varying levels of uncertainty in the design process and how it is expected to influence the nature of work and increases in efficiency through higher levels of repeatability. On the horizontal scale in fig. 4, the level of uncertainty in the building system is presented as a continuum, ranging from standardisation with a low level of uncertainty, to flexibility with a high level of uncertainty. Along the horizontal scale four positions are marked by arrows, each representing a strategic choice. The vertical scale is a schematic representation of the information requested from the client within the design process, and the degree of repetition.
RESEARCH METHOD

To analyse how the building system characteristics would affect the performance of an industrial construction company, case study research (CSR) was chosen as the research design. Yin (2003) states that when the researcher has little control over events and focus is placed on a contemporary phenomenon in a real-life context, CSR is a suitable approach. In studies of how companies in industrialised construction develop their building system, there is very little control over events for the investigators. The focus of this study is placed on a contemporary phenomenon within a real-life context. This study was performed as a single case study of one industrialised construction company in Sweden, and the unit of analysis was defined as the case company. The case company was selected based on the knowledge that the company’s previous attempts to standardise the design process had indicated the need to strategically decide in which possible ways the building system could be developed. It was also interesting since the company had a market position accepting both projects with a make-to-order setting and a design-to-order setting.

Theoretically, this creates a tension in the production process, which actually calls for separate organisations internally (Tushman and O'Reilly 1999). Data has been collected using three different methods; interviews, archival analysis and participating observations at meetings. The interviews were all semi-structured in-depth interviews with eight persons in all. Focus of the interviews
was on the current way of working in the design process as well as recapitulation of previous projects. The archival analysis was mainly focused on documentation regarding previous design projects. Data from different sources were triangulated to increase the validity of the case. This was a much needed method since the previous results from the design process were not well documented.

The study of building systems could have been done from several perspectives. The pure technical description of a building system is of interest to engineers, and contributes to the optimisation of the system performance. However, optimisation is best done on stable objects, where the basic design is well-known and will not change over a period of time. This is not the case in the case study company where the “design-to-order” strategy is permitted. Industrialised construction also has an interesting manufacturing process; where many tools from quality and lean can be transformed to work in a new context, e.g. Höök (2008) and Meiling (2008). The intention in this paper was rather to look at the role of the building system for the corporate strategy and possibly to detect success factors and pitfalls in selecting a strategy. The study is limited in the sense that only one case company is studied. However, the situation is similar in several other companies, as demonstrated by Persson et al.(2009).

RESULTS
Case company

In the housing sector, Pries and Janszen (1995) identified four different archetypes of companies, table 1, based on the three generic strategies identified by Porter (1981; 1985)

<table>
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<tr>
<th>Contractor cost leadership</th>
<th>Product company differentiation</th>
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<tbody>
<tr>
<td>Offers capacity</td>
<td>Offers product</td>
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<tr>
<td>Technology oriented</td>
<td>Market and technology oriented</td>
</tr>
<tr>
<td>Role specialisation</td>
<td>Technology specialisation</td>
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<tr>
<td>Product and market diversification</td>
<td>Process/role diversification</td>
</tr>
<tr>
<td>Varying subcontracting</td>
<td>Several product and market segments</td>
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<td></td>
<td>Specialised subcontracting</td>
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<tr>
<th>Specialised subcontractor cost focus</th>
<th>Specialised product company differentiation focus</th>
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<tr>
<td>Offers capacity</td>
<td>Offers product</td>
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<td>Technology oriented</td>
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<tr>
<td>Role specification</td>
<td>Technology specialisation</td>
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<tr>
<td>Market specialisation</td>
<td>Process/role diversification</td>
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<tr>
<td>Little subcontracting</td>
<td>Little subcontracting</td>
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The case company finds itself in the lower right quadrant (Nord 2008) and is characterised as a specialised company that offers a product with a specified technology and also has great control over sub-processes. However, the company also has a cost focus, since its heritage implies the production of low-cost dwellings, schools etc. with a touch of temporary construction to it. Falling between two categories in Table 1 is common in construction and leads to little competitive advantage (Price and Newson 2003).

The case company is part of a larger company group with four different production plants in Sweden. The product range encompasses movable personnel booths for construction sites, offices, schools, day-care centres, student dwellings and multi-storey family dwellings. The four production plants have all specialized on different types of products and the case company of this study has its main focus on residential multi-storey buildings. It is also the location where the main part of building design for residential buildings for all production plants is performed, since experience and competence levels are considered to be high from working with volumetric module production for over 50 years. The company group had in the year 2009 a turnover of 65.9MEuro and 334 employees in total at the four producing divisions. The division which is the focus of this study had a total turnover of 17.8MEuro and 99 employees.

**Design process**

The construction design department at the case company consists of seven persons, divided into the functions of Design Process Manager, Purchase, Structural Design (three persons), Electrical design and HVAC design. Design of ventilation systems, foundations and non-timber facings are purchased from subcontractors. Subcontractors are occasionally used for structural engineering as the capacity of the design process is insufficient when demand temporally peaks. This is a challenge for the building system, since it needs to be communicated not only in-house, but also to external consultants. Belonging to a larger group of companies enables the case company to use resources from other production plants. This is seen as preferable as the case company has previous experience of general construction engineers having difficulties in working in the industrialised construction context.

The case company claims responsibility for production of the building above the foundation while responsibility for the foundation preferably is handled by a subcontractor, sometimes on a separate contract with the client. If responsibility for the foundation is placed with the case company this involves additional management activities for the Design Process Manager besides providing the contractor with a foundation plan with information of bearing lines and point loads. The construction design department is also responsible for scheduling the
production and assembly phases. Labelling the building parts is a crucial part of certifying the flow of material through the entire process. Coordination of installations such as ventilation, HVAC, and electrical installation is also carried out by the design department. The building design department works with one project or occasionally two projects in parallel. An organisation with distinct roles and responsibilities has been established in a designated striving for improved efficiency of the design phase. The experience level of the personnel determines what responsibilities each person can have in a project. This specialisation has, according to the Design Process Manager resulted in reduced average total times of the construction design process.

The construction design process is divided into two distinct phases; building design and volumetric module design. The first phase is commenced with a start-up meeting. Prior to the start-up meeting, the sales department and the in-house architect have developed conceptual solutions that the client has decided to follow. To enhance the quality of the information delivered as well as ensuring that the project is suitable for the company’s building system, a function called "pre-building design” has been established. Capacity shortage in the sales department has prevented the use of the function in practice. The initial step of the construction design process is to generate 3D-models of sections, floor plans and basic plans. These are made using CAD software and are necessary for the external resources responsible for static calculations and HVAC design to initiate their work. Before the project is developed further in detail, the drawings are sent to the client for approval. After the drawings have been approved by the client, and the documentation on statics and building service systems are received, the second phase begins involving detailed development of the components of the building. There are six different functions in detailed component design: floors, external walls, internal walls, roof, claddings and the foundation. The detailed component design generates production drawings and bill of materials. Finally there is a completion meeting where the detailed component drawings are delivered to the foremen of the production process.

**Production**

Production of the volumetric units is carried out in a factory, where the units are completed to almost 90% before transport to the building site takes place. The production process builds on craftsmanship, but is organised loosely according to a conveyor belt layout. Firstly, the flat elements are produced, and secondly the volumetric units are assembled and completed, figure 2. Design and production is not integrated: drawings are delivered to the production foremen. When errors occur, the design department is alerted and the work is done again. The workers in the factory are experienced in industrial work, and in the
building system standard solutions. Specialised teams who are experienced in working with the system are employed for assembly on site. General workers and foremen do not have the experience to handle the building system, wherefore at least the foreman needs to be experienced with the system. There is no documentation of the building system with respect to assembly.

**Variety of projects and clients:**

The case company offers a mix of standardised and customised products to the client. The standardised approach involves previous attempts to create a number of made-to-order buildings that can be planned for production with only minor input in the building design process. Projects including made-to-order buildings, even with some alterations made, have total times in the design process that are short compared to average total times, table 2. Projects that involve design-to-order buildings have significantly longer total times than made-to-order projects. However, there are examples of design-to-order projects including several buildings erected in sequence, where the repetitive effect on subsequent buildings is considerable.

*Table 2. Average times per square metre for building design work. Based on total times for 22 projects during 2006-2009.*

<table>
<thead>
<tr>
<th>Type of project</th>
<th>Average times (hours/m² building area)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Made-to-order building</td>
<td>0.40</td>
</tr>
<tr>
<td>Altered made-to-order building</td>
<td>0.42</td>
</tr>
<tr>
<td>Design-to-order building</td>
<td>1.01</td>
</tr>
</tbody>
</table>

The design-to-order projects include a higher degree of uncertainty and require that the sales department deliver more information. The need for extensive information in design-to-order buildings results in additional administration for the Design Process Manager. The clients of the case company are generally co-operative building societies, real estate trustees and municipal housing companies. The experience of the client, both from construction in general but also from buying industrially produced buildings, affects the result of the construction design process. Quoting the Design Process Manager:

“[…] Some clients do not realise that when a customer specification has been made, it is not possible to change it two weeks later …”. The task of collecting information needed for the customer specification is time consuming. Due to long delivery times, 12 weeks, for windows and doors, it is
vital for the building design department to be able to determine window and door design at an early stage of a project. To gain financial benefits in material purchasing, the case company has a number of fixed contracts with material suppliers, usually agreed upon for a period of one year. This also restricts the degree of freedom regarding customer specifications as deviating from materials under a contract adds more uncertainty to the process.

There is a clear difference in opinion between the sales and the design departments with respect to the degree of adherence to the building system. The design department argues that the sales department sometimes sells projects that are difficult to realise within the constraints of the building system. It may be noted that these constraints are not clear-cut, since projects of diverse types are allowed. However, the sales department assures that they are very strict in selection of possible projects. It is beneficial for the case company to be involved as early as possible in the client’s development of the conceptual idea of the finished building. This will result in projects that are “generated from” instead of “translated to” the building system.

**Documentation of the building system**

The documentation of the building system is limited. Even if there is an evident building system present, it is previously completed projects that are bearers of the information of successful and preferable solutions. Extensive parts of the building system are only found in the heads of the persons working in the organisation. The lack of documentation of the rules of the building system is most evident. Existing documentation has two main contents: standard solutions (components) and detail specifications (joints). The standard solutions provide detailed descriptions of how components are constructed while the detail specifications explain how the connection between different components is made. There is very little information on how the two interact. Such information is not included in the documentation of the building system, but can occasionally be found in check-lists for detailed component design activities. There is also limited documentation regarding the rationale for the chosen solution and which considerations are necessary when using a particular solution. For some parts of the building system there are several possible solutions, but there is no information available of how and when they should be used.

The case company documents the building system solely using drawings which are stored on a shared directory on the internal company server. In order to create an updated building system, the case company has initiated an attempt at documenting what is described as the “current standard of the building system”. A group with representatives from sales, construction design, purchasing,
production and assembly gather on a regular basis to discuss which solutions are preferable from the perspective of the entire value chain. Product development is currently handled through acquiring new solutions in the building system from the projects that continuously are run. There is no specified process for product development, other than the documentation of the current standard which changes with time and becomes ever wider.

**CASE ANALYSIS**

**Production strategy**

The case study company has a corporate strategy that encompasses two of the production strategies described by Winch (2003). In figure 5 this is shown by the dotted rectangle.

![Figure 5. Positioning of the case study company in the analysis framework.](image)

As Winch (2003) stated the choice of two internal production strategies calls for two separate production organisations. This is not present in the case study company where every project is taken through the same production process. From table 2, it is apparent that the design process is organised to support the “make-to-order” strategy, the average design time being less than half that of “design-to-order” projects. The make-to-order strategy is well-known to all companies that work with detached houses – the private customer has a number of options to choose from in configuring a home. To a professional client a design-to-order strategy might be more straightforward since adjustments need to be made to have the new building fit into an existing building stock owned and managed by the client.
The design-to-order strategy is functional in building projects that are unique, but maybe not a one-off, i.e. some repetition is present. When looking at standardisation, it is more difficult to standardise objects when working with a design-to-order strategy than it is when working with a make-to-order strategy. The case study company has chosen to standardise and document their building system, but has not foreseen the consequences with respect to their own design process. The result is that the ‘standard’ slowly changes over time as more design-to-order projects are carried out. The amount of standard solutions increases; in this particular case also without guidelines of when to use a specific solution, and slowly the trust and meaning of a standard solution is lost since many ‘standards’ apparently exist.

Having the production strategy and the organisation aligned with each other is crucial for success. When it comes to having the organisation in-house or not this choice again depends on the clarity and documentation of the building system. With a very clear description of the building system it is possible to communicate the system to actors outside the company itself, thereby gaining from the experience and knowledge general construction engineers possess. However, working with a building system currently is not part of engineering knowledge held in common, at least in Sweden. The case study company has experiences that external engineers have trouble adhering to the system, with violation of the building system and corrupted production economy as a consequence. The lack of documentation of building system is not confined to the case study company; Persson et al. (2009) found the same situation in a study of six industrialised housing companies.

**Uncertainty**

For the company, the uncertainty in the building system is connected to market position. The case study company is active in several markets; schools, multi-storey buildings, and terraced houses. Individuals are not customers, but private developers, municipalities, municipal housing organisations and governmental bodies are customers. First of all, this means that the case study company needs to be cognizant of the rules and preferences of all these clients – if not, uncertainty arises. Secondly, since contracts are almost solely design-build contracts, the case company needs to coordinate all other consultants such as HVAC, elevators, stairs, electrical wiring, and foundation consultants. In each of these interfaces, uncertainty arises that slows the process. Thirdly, the willingness of the client to comply with the industrialised process is important. The client in the field of construction is used to being able to make changes at late stages in the building process, which is one of the benefits with the construction culture. For an industrialised process this is devastating as
decisions at a late stage cannot be incorporated, and unsatisfied clients are the result. This kind of uncertainty can be addressed through information, but it poses difficulties every time a new client is contracted. The sales department has central role in creating success for the housing company. If they sell projects that are not in compliance with the building system lower company profit will result. Therefore, the competence of a salesperson employed by an industrialised builder must be soundly based regarding production.

The kind of uncertainty that arises at the case study company mostly comprises project complexity. The case study shows that coordination of actors is a major task, especially when new actors enter the stage. Technology novelty is not high as most structural problems and new solutions can be resolved by looking at older projects. It may be noted that this does not imply looking at the ‘standard’ under development. The aforementioned indicates that product orientation is not the way forward under current conditions: project complexity is the task that is difficult, so process support is needed. A more advantageous route ahead would be through process orientation and standardisation.

**The production strategy works against the business strategy**

When looking at the situation at the case company and how they are organised in relation to what tasks they actually take on it is clear that a strategic dissonance is present. The intended strategy from the company is to create made-to-order buildings that can be offered to the market. However, the demands of the market are for greater flexibility. This means that a design-to-order approach would be more appropriate. The design process at the case company is organised according to a made-to-order strategy, which results in poor performance and high levels of uncertainty when design-to-order projects are taken through production. The product orientation chosen does not provide a good basis for a high degree of flexibility and to succeed with the current direction the case company would need a large market in terms of volume to achieve economies of scale.

Seen over a longer period of time (50 years), the construction market in Sweden has changed from large scale projects producing housing for populations moving to the cities towards smaller projects, filling in gaps in the city plan and refurbishing housing. The economy of scale approach currently is not strategically a good fit for the market. The case company tries to adjust to market needs by allowing different types of projects to enter the production system. This is understandable when the economy of the building sector is poor, but to be a successful actor with a strategic fit, you need to be excellent in your chosen niche. The case company has many competitors in its market sector; not only industrialised construction companies, but also general construction
companies. For other companies wanting to engage in industrialised construction, this situation can be a lesson. To succeed in industrialised construction, the business strategy and the production strategy must be in harmony with the market; otherwise poor performance will result.

Even if a mass-production approach cannot be considered as fully applicable for industrialised construction due to the perceived demand for unique one-off products, the main case company is determined to work with continuous improvement of the processes of the company. This is of course a sound decision, but it does not seem to be carried through in a logical order. The essence of a business strategy is to stand by an idea and carry it through all the way from sales to assembly. Continuous improvements are of no use if the business strategy is not followed through; the processes are seldom stable enough to allow continuous improvement. Instead, uncertainty arises when only partially known processes are introduced in the company when new projects start and poor performance follows.

The building system is a strategic asset

From a resource-based view, the building system qualifies as a firm-specific strategic asset. It is of value to the firm, since it improves efficiency through offering standards and stability in design and production. The building system rare, as knowledge of the building system is built-in over decades and solutions have been gradually tested and have become robust. The building system is also imperfectly imitable, mostly for historical reasons since the experience built into the system is difficult to replicate, but also because long-term customer relations have been built up by the company. The building system is easy to substitute if competitors in the niche are engaged, but hard to substitute when looking in general construction.

However, the building system is not managed and recognised as a strategic asset by the case company. The production capability is the strongest capability of the case study company, but a constant struggle between design and production hinders an efficient flow of information, which results in low flow rates. The market management capability is not in tune with production. For example, salesmen sell housing that lies outside the current building system, which results in low profit. The key role of the salesmen is not recognized. The salesmen’s knowledge of the building system is insufficient. This is coupled to the poor documentation and maintenance of the building system. Product development does not exist, which leads to gaps between market, innovation and production. The case company needs to recognise their building system as a strategic asset and to manage it accordingly.
DISCUSSION
When looking at the building system it is interesting to reflect upon the opportunities and hindrances a building system offers:

- Many of the procedures and processes are the same in different projects even if the product differs. Standardisation of processes is therefore a possible way forward, apart from standardisation of the product itself. Standardisation of the processes might also give a better payback economically, since much time is spent on coordination and searching for information to reduce uncertainty. A possible effect on the uncertainty of using a building system is presented in figure 6.

![Figure 6. Possible reduction in initial uncertainty when using a building system.](image)

- When actors (clients, subcontractors, material suppliers) are tied to the process in a more consistent manner, the learning effect becomes greater and efficiency increases. This is dependent on a stable market situation which enables actors to plan ahead for longer than a few months. Long-term relationships are the key to success in industrialisation since stable supply chains enable continuous improvement.
- The interfaces recur and can be standardised. This is the single largest source of uncertainty, which can only result in reduction of uncertainty if stable relations with other actors are established.
- If it is impossible to take control over other actors, uncertainty can be reduced through internally taking control over most activities, i.e. in-house resources. Outsourcing is therefore not a concept that is well-suited to industrialised builders in the build-up phase. Their building system must be very well documented and their relations with other actors stable for outsourcing to be effective.

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Currently the hindrances for making the building system work properly exceed the opportunities:

- The project-orientation in construction makes it difficult to actually measure the performance of the process. Currently, only the outcome of finished projects is reported and due to the uniqueness of every project, comparison between different projects is considered to be difficult or impossible. Continuous improvements are difficult to work with if they cannot be measured properly. The project structure makes it difficult to find receivers for experience feedback. There is currently no ICT system that facilitates retrieval of information from previous projects.

- The documentation of the building system is poor. Drawings and standard solutions exist, but there is no advice on how to handle different situations such as in sales. The documentation is not connected to any business strategy, i.e. the strategic importance of the building system is not recognised. This can be a problem of communication between engineers and managers because their measures of good performance differ.

- The building system is not recognised and managed as a strategic asset of the company. Its importance for the company’s success is not fully appreciated. The building system is the foundation for what market to target, but also the foundation for the production strategy. It is actually a physical link between the market view put forward by Porter (1981; 1985) and the resource-based view presented by e.g. Hamel and Prahalad (1994).

- The use of ‘black-box’ solutions in construction is not the current mode of conduct. A building system is considered a ‘black-box’ in the sense that the client cannot change every part of the system. Occasionally, this results in excessive static calculations and requirements to deliver information about the building system’s long-term performance. The uncertainty perceived by the client is high.

Selecting the strategy of working with a building system is the first step towards moving from project orientation towards process orientation. Many benefits can be gained through this movement, but great efforts needs to be made by the company owning the building system. The very first step is to make the business strategy go hand-in-hand with the organisation of production. Still, it is very difficult to go through with this, since the current construction culture is about solving the problem period, not solving the problem permanently (Höök 2008).

FUTURE WORK

The market perspective and the core competences of a company are of interest to further explore. The building system offers a physical link between these two approaches to strategy and therefore it should be important to analyse its
function by means of case studies of other companies. The selection and development of strategies for smaller firms relying on the heavy investment that lies in a building system also should be of interest. The interaction between standardisation and flexibility is at the core of designing a building system. Currently, building system design seemingly is performed with a technology focus. If a change was made to a business focus, or a combination of the two, other results might emerge than the current production/technology focused offer.

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