Industrialised House-Building - Conceptual orientation and strategic perspectives

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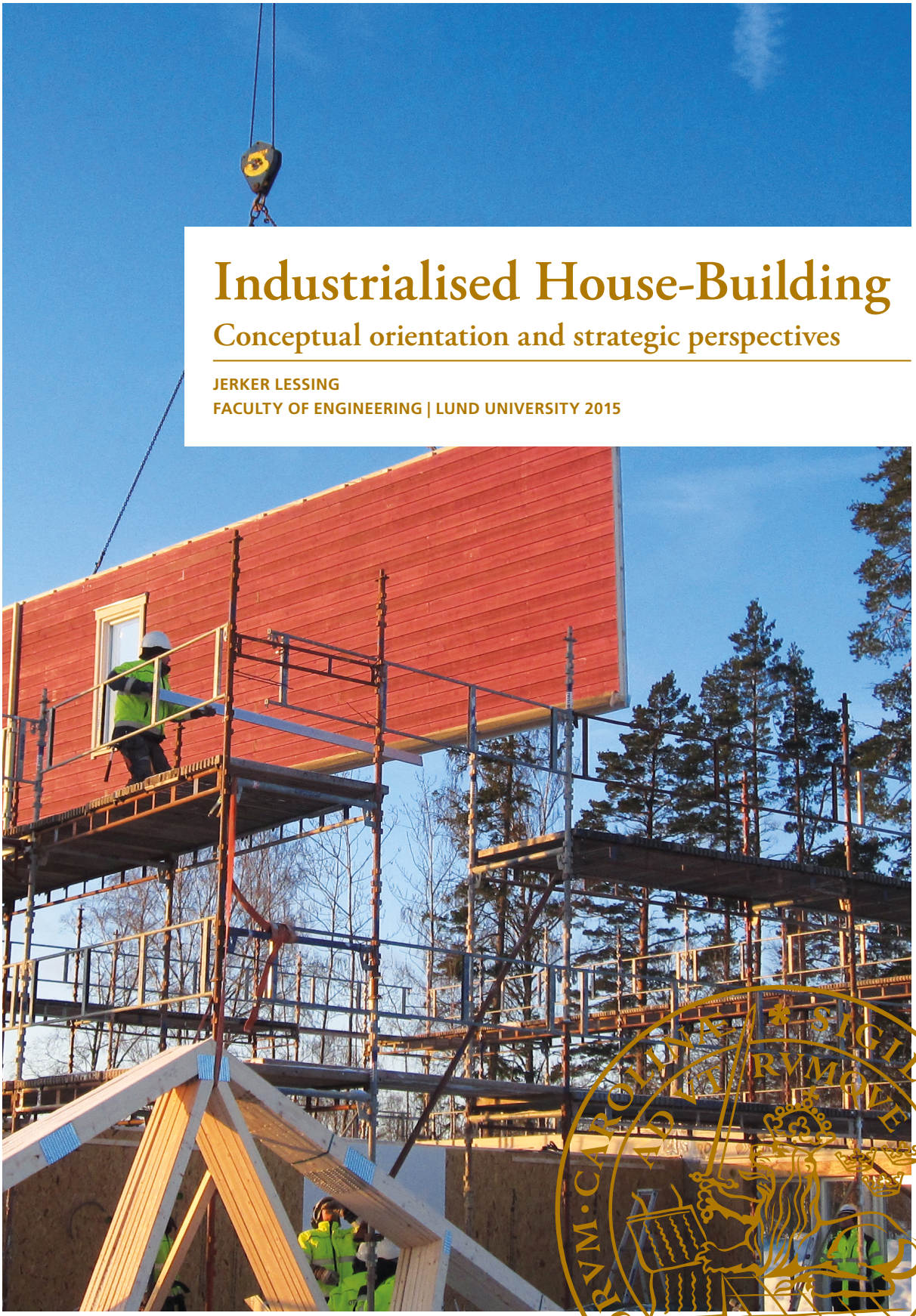

Industrialised House-Building

Conceptual orientation and strategic perspectives

JERKER LESSING
FACULTY OF ENGINEERING | LUND UNIVERSITY 2015

INDUSTRIALISED HOUSE-BUILDING

CONCEPTUAL ORIENTATION AND STRATEGIC PERSPECTIVES

Jerker Lessing

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DOCTORAL DISSERTATION
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Abstract

Industrialised house-building has received increasing attention within both the construction industry and the scientific community during the last 15 years. However, industrialisation of house-building is not a new phenomenon, it has been applied to various extents throughout modern history, although the understanding and descriptions of it have developed over time. Scientifically, industrialised house-building has mainly been investigated through partial studies, and a holistic description of the field has been lacking.

The purpose of this research is to holistically describe the characteristics of industrialised house-building and explore associated strategic perspectives and business models, in order to improve understanding of the phenomenon. The research is based on qualitative case study methodology together with literature studies. The findings were used for theory refinement and jointly contributed to the composition of a conceptual framework and elaboration of strategic orientations and business model analyses for industrialised house-building.

Industrialised house-building is found to be characterized by a set of 12 inter-related constructs that require systematic integration, in order to establish production systems, structured for continuous production of buildings, aimed at certain market segments and product ranges. Industrialised house-building companies generally derive from either a market-based Outside-In perspective or a resource-based Inside-Out perspective. These perspectives reflect the companies' starting points and are indicative of three main strategic orientations when combined with their product pre-definition levels and potential market cover (which ranges from niche to broad).

A characteristic feature of industrialised house-building companies' business models is the establishment of a tight fit between market segment requirements and offerings, based on product platforms enabling customization within defined limits. The structure and utilization of operational platforms is characterised by high control of both product configuration and production processes.

Key words: Industrialised, house-building, strategic, business model, product, platform, orientation

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To my beloved Lisa, Astrid and Anton

The secret of getting ahead is getting started

Mark Twain

Contents

Preface

Construction and house-building play important roles in our society, not only affecting our built environment, people's homes and living spaces, but also the financial system, the environment, the competitiveness of regions and cities and (thereby) also politics. This makes it very complex but also very interesting!

This thesis is about the development of industrialised house-building and its strategic perspectives and business models, highlighting opportunies for companies to deal with some of the challenges in our industry.

I have actively participated in this part of the construction industry for more than 15 years, and involved in numerous development projects as an industry consultant and as a researcher. My most important contribution, has been to actively transfer knowledge from the industry to the academic community and vice versa. This is also the overarching purpose of this thesis; to increase the theoretical understanding about industrialised house-building by combining knowledge from the industry with theories and models from the literature and thereby contribute to the development of the industry!

The development of industrialised house-building gives companies increased competitiveness and opportunities for expanding their offers and exploring new markets. This includes the possibility to contribute to a sustainable development of house-building in a global perspective, indicating the width and potential that industrialised house-building embraces! There is an extraordinary potential in combining the wealth of academic theories, models and principles, with the entrepreneurship and deep knowledge of the industry. I look forward to continue my contributions, with this research as an important foundation.

I hope that you, the reader of this thesis, find it interesting and that you will be inspired to contribute to further development of house-building. Please contact me if you want to discuss the content of this thesis in particular or development of house-building in general!

Jerker Lessing

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This research project was conducted at the Division of structural engineering within the Department of Building and Environmental Engineering at Lund University. The project has been generously financed by Sven Tyréns Stiftelse and by the research programme Lean Wood Engineering, for which I am very grateful.

Many people have contributed throughout the course of this research project, for which I am deeply thankful. First and foremost I would like to mention my supervisor Professor Anders Ekholm and my assistant supervisor Professor Lars Stehn. Anders, thank you for supporting and guiding me through my academic work ever since 2004. Thank you for your valuable advice, sharp analyses and for letting me find my own way! I think we have learned a lot together. Lars, thank you for your generous support, encouragement and for teaching me so much! Thanks also for always sharing your enthusiasm, energy and good advice! I am very grateful for all your support and I look forward to continue our work together! Also Professor Carin Andersson and assistant Professor Miklós Molnár have acted as assistant supervisors and contributed with valuable advice and supported me in practical issues.

When I returned to Lund University for this research project, Professors Sven Thelandersson and Annika Mårtensson generously welcomed me to join the division. This meant a lot to me and I have truly enjoyed the friendly atmosphere and your support during my time here!

I would like to mention Professor Staffan Brege who has taught me about strategy and business models and co-authored two of the articles in this thesis. I have truly appreciated our collaboration and interesting discussions. Thank you Staffan for all your advice and support! The former vice president of Tyréns, my mentor and friend, Tomas Alsmarker encouraged me to continue my research. Thank you Tomas for your constant support and great enthusiasm. You have given me energy so many times during more than 20 years! Mats Persson, business unit manager at Tyréns has also always supported and helped me in so many ways. Thank you for all this! Laine Montelin, my colleague at Tyréns, thank you for support, help and friendship. The three of you have taught me so much and I am deeply grateful and happy for our friendship and collaboration! Thanks also to Birgitta Olofsson, vice president at Tyréns, managing the company's R&D, for helping me throughout

this research project. And to all other colleagues at Tyréns; thank you for great collaboration in many interesting projects!

In 2013, I spent four amazing months as a visiting researcher and lecturer at Stanford University, USA, invited by Professor Martin Fischer, for which I am very thankful. I would also like to thank all my students at Stanford, for showing such interest and curiosity in industrialized house-building. A special thanks to Charles Bovet, José Goldaracena and Ramon Dario Iglesias for your extraordinary enthusiasm and entrepreneurship when we organized the course for a second time at Stanford in 2014 and the study trip to Sweden. What an adventure!

Emile Hamon, my friend, thank you for your constant support, your good advice and help in big and small projects! Thanks also to Christoffer Persson for coaching and encouraging me! My three different room mates at the division: Linus Malmgren, Martin Fröderberg and Ivar Björnsson; thank you for valuable discussions and not least, great coffee breaks and laughs!

I am deeply thankful to all the generous people I have met in the house-building industry throughout this research project, and who have contributed with valuable information and opened your companies for me. Thank you all! I would also like to thank all colleagues at Lund University and within the Lean Wood Engineering programme as well as the ProViking programme, for interesting courses, seminars, discussions and collaboration.

And to all my friends: thank you for your support and encouragement! It means a lot!

Last but certainly not least, I want to mention my family. My mother, my father and my sister; without your endless support, love and help, I would not be where I am! And, Lisa my love, you and our wonderful children Astrid and Anton, are my sunshine and the greatest supporters of them all! Thank you for your infinite support, for taking care of me and pouring your love over me! My love to you is higher than the sky and deeper than the sea!

Barsebäckshamn, October 12, 2015

Abstract

Industrialised house-building has received increasing attention within both the construction industry and the scientific community during the last 15 years. However, industrialisation of house-building is not a new phenomenon, it has been applied to various extents throughout modern history, although the understanding and descriptions of it have developed over time. Scientifically, industrialised house-building has mainly been investigated through partial studies, and a holistic description of the field has been lacking.

The purpose of this research is to holistically describe the characteristics of industrialised house-building and explore associated strategic perspectives and business models, in order to improve understanding of the phenomenon. The research is based on qualitative case study methodology together with literature studies. The findings were used for theory refinement and jointly contributed to the composition of a conceptual framework and elaboration of strategic orientations and business model analyses for industrialised house-building.

Industrialised house-building is found to be characterized by a set of 12 inter-related constructs that require systematic integration, in order to establish production systems, structured for continuous production of buildings, aimed at certain market segments and product ranges. Industrialised house-building companies generally derive from either a market-based Outside-In perspective or a resource-based Inside-Out perspective. These perspectives reflect the companies' starting points and are indicative of three main strategic orientations when combined with their product pre-definition levels and potential market cover (which ranges from niche to broad).

A characteristic feature of industrialised house-building companies' business models is the establishment of a tight fit between market segment requirements and offerings, based on product platforms enabling customization within defined limits. The structure and utilization of operational platforms is characterised by high control of both product configuration and production processes.

Sammanfattning

Industriellt bostadsbyggande har fått ökande uppmärksamhet inom såväl byggindustrin som den akademiska världen under de senaste 15 åren. Som fenomen är industrialisering av byggandet dock inget nytt utan har historiskt tillämpats med varierande grad, däremot har betydelsen och beskrivningen av detta varierat över tid. Vetenskapligt sett har industriellt bostadsbyggande huvudsakligen utretts i partiella studier och en helhetsbild och övergripande beskrivning har saknats.

Syftet med denna forskning är att beskriva industriellt bostadsbyggande och dess karakteristik, samt utreda de strategiska perspektiv och affärsmodeller som relaterar till detta, med målet att öka förståelsen kring detta. Forskningen baseras på kvalitativ fallstudiemetodik och litteraturstudier. Resultaten har använts för teori-förfining och har också bidragit till att ett konceptuellt ramverk satts samman samt möjliggjort identifiering av strategiska riktningar och analys av affärsmodeller för industriellt bostadsbyggande.

Industriellt bostadsbyggande beskrivs och karakteriseras av en sammansättning av 12 delområden som är inbördes beroende av varandra. Dessa behövs för att tillsammans bidra till att produktionssystem kan etableras och skapa en struktur för kontinuerlig bostadsproduktion, som inriktas mot utvalda kundsegment och produktvariation. Företag som arbetar med industriellt bostadsbyggande härstammar antingen från ett marknadsbaserat Utifrån-In-perspektiv eller från ett resursbaserat Inifrån-Ut-perspektiv. Dessa perspektiv återspeglar företagens ursprung och tre huvudsakliga strategiska riktningar har identifierats utifrån analys av företagens användning av förutvecklade produktstrukturer samt den potentiella marknad som täcks in (som sträcker sig från nischad till bred).

Ett utmärkande drag för affärsmodeller för företag som arbetar med industriellt bostadsbyggande, är att krav från marknaden och företagens erbjudande noga passas ihop med varandra, samt att affärsmodellerna baseras på produktplattformar som möjliggör kundanpassning inom definierade gränser. Produktplattformarna ger företagen möjlighet till hög kontroll över såväl produkternas konfiguration som produktionsprocesserna.

Introduction

Background

Attention on industrialised house-building

During the last 15 years industrialised house-building has received increasing attention within both the Swedish construction industry and the scientific community. However, industrialisation of house-building is not a new phenomenon, it has been applied to various extents throughout modern history. Single-family houses have been produced using industrialised methods, to some degree, since the early 1900s (Davies, 2005) and during the 1960s many European countries executed large-scale housing programmes, notably the Million-homes programme in Sweden which partly applied industrialised house-building (Hall and Vidén, 2005). They subsequently fell out of favour, due to an abruptly decreasing housing market and to criticism of the social and technical quality of the housing areas (Engfors, 1987). However, industrialised house-building was re-introduced by Swedish building companies in the early 2000s, also pin-pointed in several investigations that identified needs for the construction industry to develop within a variety of areas (Byggkostnadsdelegationen, 2000, Byggkommisionen, 2002). This thesis addresses industrialised house-building and its contemporary development, largely from a company-strategic perspective.

Conceptually, industrialised house-building is considered to be an integrated process-oriented phenomenon that involves several theoretical fields (Lidelöw *et al*., 2015), characterized by long-term relations in the supply chain and production system, aimed at selected markets, through product approaches (Barlow and Ozaki, 2003, Winch, 2003, Björnfot and Stehn, 2007), with a high degree of product predefinition (Jansson *et al*., 2014).

House-building companies applying such processes require markedly different structures concerning utilization of technical solutions and systems, organization, processes and supply chains from those of traditional building companies (Goulding *et al*., 2014). These are strategic issues affecting how companies operate, what they offer and the roles they adopt in the value chain.

Consequently, following the recent resurgence in interest there is a need for further clarification and characterization of industrialised house-building, through a definition based on theoretical rigor and empirical analysis of companies' development and applications. Considerations of strategic perspectives will contribute to an enhanced and relevant understanding of various viewpoints, key elements and applications of industrialised house-building.

The situation in Swedish construction is regarded as being similar to the situation in many other developed countries, as widely reported on within literature. Construction is characterized as an industry producing complex one-of-a-kind projects, in temporary organizations using mainly on-site production methods (Gann and Salter, 2000, Gosling and Naim, 2009). Supply chain integration is scarce due to a fragmented process dominated by short-term relations (Cox and Ireland, 2002) and design is carried out by temporary design teams, from different consulting firms. A variety of contractors are engaged to produce unique buildings, with project-specific production methods (Naim and Barlow, 2003). This offers limited incentives and possibilities to establish methods, design solutions and processes that can be systematically repeated and improved (Gadde and Dubois, 2010).

About this thesis

The research presented in this thesis is partly based on earlier work presented in my licentiate thesis (Lessing, 2006), however mainly based on following work specifically focused on the development of industrialised house-building and company-strategic perspectives and business models. The licentiate thesis presented industrialised house-building as an integrated, multi-disciplinary process that requires an established production system, continuously used by a company or network of closely collaborating companies. A production system is, in this context, the structure of resources and capabilities that are integrated and organized to enable repetitive production of a selected range of products. This includes design, technical systems, production facilities, knowledge, collaboration, supply chain activities and information management, (cf. Liker, 2004, Ohno, 1988). The development of industrialised house-building is connected to how companies are structured and managed, thus this thesis is focused on strategic aspects of companies' development and utilization of industrialised house-building.

Industrialised house-building

During the last decade several companies in Sweden and elsewhere have developed and brought to the market new industrialised house-building concepts, based on process innovations and product platforms (Lidelöw *et al*., 2015). Knowledge and inspiration have been introduced from other industrial sectors that have developed and implemented innovative methods and principles for design, production and supply chain (Gann, 1996, Barlow *et al*., 2003).

A comprehensive view of industrialised house-building

In the large-scale industrialisation attempts during the 1960s, prefabrication and standardised technology were widely applied, and called industrialised building (CIB, 1965). The perception of industrialised house-building during the first years of the 2000s was partly based on such historical descriptions, with mass production still at the core of the concept (Goodier and Gibb, 2007). However, a more comprehensive understanding was emerging (Gann, 1996, Barlow *et al*., 2003) and broadening the scope. Various terms have been used when referring to industrialisation of construction, though. Pan and Goodier (2012) claim that "offsite production/construction/manufacturing", "preassembly", "prefabrication", "system building", "modern methods of construction" and "industrialized building" are terms with subtle differences and can be largely used interchangeably to describe pre-fabricated construction. These definitions take a common stand-point in focusing on production methods and prefabrication, but industrialisation is a phenomenon that not only involves production issues but also process-, collaboration, supply chain and market issues (Gann, 1996).

In literature, a majority of the publications covering industrialised house-building and related concepts provide only partial descriptions of the phenomenon, which stresses the need for a holistic description embracing its width and diversity. During my earlier research, a comprehensive, conceptual framework for describing the content and process structure of industrialised house-building was developed and presented in an article (Lessing *et al*., 2005) and subsequently in a more elaborated form in the licentiate thesis (Lessing, 2006). This was one of the first attempts to acknowledge clearly that industrialised house-building integrates several constructs, of which prefabrication and building systems are essential for controlling the production, but not sufficient to define or describe what industrialisation is. This more comprehensive view has been subsequently advocated by increasing numbers of authors, and notably Goulding *et al*. (2014) state that it is crucial to integrate off-site construction with new relationships,

skills, technology, processes and methods, in order to accelerate change and improvements in the house-building business process.

An important difference between traditional, project-oriented building companies and industrialised house-building companies is that the latter need to establish a structure for managing not only continuous processes for developing and managing their production system and associated sub-systems, but also the execution of building projects. This combination of continuous processes and discrete projects was described in the licentiate thesis (Lessing, 2006), stressing that such a structure requires appropriate strategic company decisions, as also emphasized by Höök *et al*. (2015).

Product approach and business model

Product platforms are central elements in the development of industrialised house-building (Jansson *et al*., 2014). Such systems are interchangeably called building systems, technical platforms and product platforms. In this thesis, however, the term product platform is used, based on the descriptions by Meyer and Lehnerd (1997). Product platforms provide a structure for pre-defined technical solutions, requiring thorough documentation and continuous improvements, serving as a backbone for technical information and related processes and methods in a company and its related supply chain (Johnsson, 2011). The level of predefinition of solutions is of strategic nature, since it affects what type of buildings the company can offer, how they should be produced and how much effort should be spent on developing the system. Hvam *et al*. (2008) recognise four levels of product predefinition, ranging from traditional project-unique design, through two levels of platform development, to completely pre-defined products. This shares similarities with descriptions by Winch (2003) of four production strategies and related design strategies, i.e. coupling the product predefinition with suitable production methods that constitute important parts of a company's production system. These levels represent the variety in product strategies, implying that production systems and company structures should be tailored to suit the company's offerings and execution (Robertson and Ulrich, 1998).

Industrialised house-building leads to various consequences for companies applying it. Decisions are required regarding the kind(s) of buildings to focus upon and a corresponding production system integrated with a product platform needs to be designed and developed (Jonsson and Rudberg, 2014). All this requires investments in the development of people, methods and hardware (Brege *et al*., 2014), together with adaptations of organizational structure (Gerth, 2013).

Further, the company needs to make strategic choices regarding market segments to target, based on market analyses (Hedgren and Stehn, 2014), which will also influence decisions concerning product ranges and hence the product platform and production system required.

The decisions consequently influence the company's flexibility in the market and ability to handle market fluctuations, as well as potential market constraints associated with municipalities' and authorities' regulations (Viking and Lidelöw, 2015). It is stated that industrialised house-building leads to specialisation and affects companies strategically, in terms of their operations, offerings and roles. Thus, there is a need to explore and describe industrialised house-building from a strategic perspective. However, there have been few attempts to meet this need as yet (Pan and Goodier (2012) and a distinct knowledge gap is identified. It is therefore crucial to clarify critical, strategic factors that affect companies applying industrialised house-building, and this was a key objective of the research this thesis is based upon (hereafter this research).

A production system can be established via two main strategic perspectives: based on the company's capabilities, following the resource-based view (Teece *et al*., 1997), or following a market based view (Porter, 1996). These alternatives are well-known perspectives from the theories about strategy and operations management. In a market-based, outside-in approach to business model development, market and customers' demands and needs are the starting points for formulating the company's offers (Porter, 1996). The offers provide input to product development and dictate the production and supply chain resources required to enable competitive provision of the offers (Porter, 1985). A market-based, outside-in perspective on business model development use market- and customers' demands and needs as the starting point for formulating the company's offers (Porter, 1996). The offers provide input to product development and dictate production and supply chain resources required to enable competitive provision of the offers (Porter, 1985). Trade-off considerations are also important, i.e. decisions about what to leave aside, in order to maintain a distinct line of strategy development and focus in the organization (Porter, 1996). In contrast, in a resource-based, inside-out perspective, the organization's core competences and resources are used as the starting points for strategy formulation (Prahalad and Hamel, 1990). Offerings are shaped based on the company's strengths, and markets with demands for such offerings are sought (Wernerfelt, 1984). A fundamental requirement for this approach is the ability to exploit internal and external competences to deliver value creation and competitive advantage (Teece *et al*., 1997).

Industrialised house-building companies are relatively new on the market and their business logic differs from that of traditional building companies (Brege *et al*., 2014). Therefore, there is a need to clarify how such companies are composed, develop and operate. Business models are constructs suitable for such descriptions and analyses, explaining the logic of companies and how they operate (Baden-Fuller and Morgan, 2010). More specifically, business models include descriptions of customer characteristics, what the customer values, how profit is made and how value is delivered (Magretta, 2002). Strategic choices are fundamental elements in the formulation of business models, and their profound consequences for the company highlight the importance of successfully integrating business models' components (Casadesus-Masanell and Ricart, 2010).

The characteristics of, and issues associated with, the business models of house-building companies applying new methods and offers have been sparsely researched. Pan and Goodier (2012) reviewed research literature on business models related to off-site construction and concluded that the knowledge base is scant and needs to be enhanced to increase understanding about this kind of company in the house-building sector. Goulding *et al*. (2014) also emphasize that greater knowledge and characterization of business models are crucial for the uptake of new concepts in the construction industry. Brege *et al*. (2014) introduced a business model framework for industrialized building, with prefabrication as the starting point, composed of three main building blocks: the offering, the operational platform and the market position.

Information regarding a production system from an operational perspective, combined with a holistic company-strategic perspective, outlines the company's market position in the value chain along with its core offerings which are crucial components for complete business model descriptions. Several of these elements of industrialised house-building companies' business models require further exploration. Thus, they are addressed in this thesis, which is conceptually rooted in the outline of business model composition presented by Brege *et al*. (2014), but with product-orientation as the starting point. By combining a product-oriented approach with a strategic perspective and business model approach, knowledge about this almost un-explored aspect of industrialised house-building is brought forward. This contributes to the understanding of critical factors affecting industrialised house-building companies' business models, included components and its' relations.

The purpose of this research

The purpose of this research is to increase understanding about industrialised house-building, in a company-strategic perspective, through exploring and describing the components and structure of industrialised house-building processes and systems, then examining strategic orientations and the characteristics of industrialised house-building companies' business models.

Research questions

Based on the purpose, the following three research questions are posed:

What characterises industrialised house-building?

The concept has an inter-disciplinary nature and is composed of several integrated theoretical constructs, hence both the component constructs and the holistic structure need to be described and explained.

What characterises the strategic orientations of industrialised house-building companies?

To implement industrialised house-building companies need to increase their technological and market specialisation, by optimizing production methods, supply chains and selecting suitable market niches.

What characterises the business models of industrialised house-building companies?

The specialisation of industrialised house-building companies emphasizes the need for clarifying such companies' business models. The fit between the business model's components and with the surrounding market environment need to be explored, along with how companies' strategic perspective and choice of product predefinition affect the business model set-up.

Position taken for this research

The underlying rationale of this thesis is that industrialised house-building can be described as a set of integrated, inter-dependent constructs that form continuous processes embedded in production systems. Further, industrialised house-building affects how companies apply and structure their technological solutions, processes and production methods in relations with customers and partners. It is recognized that companies that apply industrialised house-building (successfully or not) have affected how the "theoretical" concept industrialised house-building has developed, a consequence of close links between research and development in academia and industry. These are important reasons why industrialised house-building is considered from a strategic company perspective here. Business models are seen as suitable tools for describing and analysing companies, in terms of internal structure and set-up, as well as their relations with the surrounding market environment.

Appended research articles and related work

Research article I: Lessing *et al.* (2015) "Industrialised house-building – development and conceptual orientation of the field"

The article presents a description of the emergence and development of industrialised house-building, based on an extensive literature review and a case study executed over nine years. A conceptual framework is presented that describes industrialised house-building as an integrated concept that includes important elements of company-strategic dimensions.

The article's authors are Jerker Lessing, Lars Stehn and Anders Ekholm. It was submitted to the journal Construction Innovation – Information, Process, Management, and accepted for publication in April, 2015. Jerker Lessing's contribution was formulating the fundamental ideas, together with Lars Stehn and with support from Anders Ekholm. The empirical material used in the article is partly from Lessing's licentiate thesis, however complemented with an extensive literature study and continued case study, which was carried out by Jerker Lessing. The research material as a whole was structured, coded and analysed equally by the authors. The text in the article was written mainly by Jerker Lessing, however supported by Lars Stehn and Anders Ekholm that contributed to and improved the text.

Research article II: Lessing and Brege (2015a) “Business models for product-oriented house-building companies - experience from two Swedish case studies”.

This article describes the business models of two Swedish product-oriented house-building companies, based on case studies. The results show that these companies have developed from a market-based perspective, offering houses and apartments to clearly defined customer segments.

The article’s authors are Jerker Lessing and Staffan Brege. It was submitted to the journal Construction Innovation – Information, Process, Management in February, 2015, and accepted for publication in July 2015. Jerker Lessing formulated the fundamental ideas, with support from Staffan Brege. The case study was planned by the authors together and executed during one year, 2013-2014 by Jerker Lessing. The research data was thereafter coded, structured and analysed by the authors together, while the writing of the article was done mainly by Jerker Lessing, however assisted by Staffan Brege who contributed by adding to and improving the article.

Research article III: Lessing and Brege (2015b) “Exploration of industrialized building companies’ business models – a multiple case study of Swedish and North American companies”.

This article is based on a multiple case study including ten industrialised building companies in Sweden and the U.S.A. The results show how the companies’ strategic perspective and choice of product predefinition affect the business model set-up.

The article’s authors are Jerker Lessing and Staffan Brege. It was submitted to the journal of Construction Engineering and Management, in September, 2015. Jerker Lessing formulated the basic idea for the article, which was refined by the authors together. Jerker Lessing carried out the case studies, with some assistance from students at Stanford University in California, USA and from students at Lund University, Sweden. The case study material was structured by Jerker Lessing and analysed by the authors together. The article was written mainly by Jerker Lessing, although Staffan Brege assisted and contributed to the text.

Other publications

Conference article: Lessing et al. (2005) "Industrialised housing – definition and categorization of the concept"

This article was presented at the conference organized by the International Group for Lean Construction in July, 2005. The article describes the industrialised housing concept as having eight key characteristics, based on two case studies and a literature study.

The article's authors are Jerker Lessing, Lars Stehn and Anders Ekholm.

Licentiate thesis: Lessing (2006) "Industrialised house-building – Concept and Processes".

This thesis was the result of Jerker Lessing's 2½ years research project for the Engineering Licentiate degree. The thesis describes three extensive case studies of Swedish companies implementing industrialised house-building, along with an extensive historical description of the field as well as a literature study describing the contemporary development. A conceptual framework was presented in the thesis, describing the field of industrialised house-building, its included parts and process structure separating continuous development from project execution.

Jerker was the sole author of the thesis, however supported by his main supervisor Professor Anders Ekholm and assistant supervisor Ass. Professor Niclas Andersson. The thesis was published and presented at a licentiate seminar in September, 2006.

Technical report: Industrialized building - A multiple case study of companies in Sweden and North America

This report describes Swedish and North American companies applying industrialised building. The report format allows richer descriptions and illustrations than is possible in research articles and hence contributes to understanding of the companies' concepts and business models.

The report was authored by Jerker Lessing as the sole author, published in October 2015.

Methodology

Researcher's context and background

For me, as a researcher, my background and context affects the way I see, interpret and understand phenomena around me. Therefore, it is important to describe my background and the context I have been acting within, since it has an impact on my research (Lincoln and Guba, 1990).

Since leaving school I have constantly mixed education and academic studies with work in industry. Immediately after high school, in 1991, I worked for a year at a construction engineering firm, then completed a two-year bachelor's degree in construction engineering, before working for a year again at a structural engineering firm (during 1995), mainly involved in structural design for traditional building projects. The following year, I returned to Lund University to become a civil engineer. During my studies I was attracted to both technical subjects and more process-related subjects, and my master's thesis explored supply chain management as an enabler for efficient building processes.

After receiving my MSc in civil engineering, in 2000, I worked for two years as a structural engineer at one of Sweden's largest engineering firms, Tyréns AB. I became deeply involved in the development and launch of a new timber-based building system. In 2002, I co-founded a small consulting company, together with two friends, focusing on process development in the construction industry. During 2003 I was also assigned to investigate the Open House building one of the pioneers of contemporary, large-scale industrialised house-building in Sweden.

In 2004, I was offered the opportunity to return to Tyréns, to become a company-financed PhD student engaged in research about industrialised house-building. I completed a program as a part-time researcher at Lund University. The research project offered an excellent opportunity to combine my interests in technology and process development. The research resulted in a licentiate thesis, which I presented in 2006.

After finishing my research I returned to Tyréns to exploit my new knowledge as a consultant. I was assigned a business developer's role, to establish a new field of competence within the company and collaboration with companies in the Swedish

construction industry interested in developing or implementing industrialised house-building. The interest was massive and we were soon involved in several large initiatives, aiming to develop new building systems, new processes, IT-tools and supply chains. During this period, and ever since, I have been asked to give numerous presentations to explain and describe industrialised house-building at meetings and seminars organised by companies, universities, political organizations and authorities. During this period, starting in 2007, the large joint industrial and academic research programme Lean Wood Engineering (LWE) was launched and executed in Sweden, focusing on industrialised house-building. I was involved as industry representative. In 2010, LWE organized a study trip to Japan, which I joined, and our delegation visited several industrialised house-building companies. Through involvement and participation in LWE I had the opportunity to keep abreast of the latest findings, and strengthen links with a network of researchers and companies determined to promote the development of industrialised house-building, both academically and commercially.

During a 6-year period I was deeply involved in numerous development and consulting assignments, which gave me hands-on experience and valuable knowledge about developing and implementing industrialised house-building.

In 2011, I had the opportunity to resume academic study, financed by Tyréns, to complete a doctorate, through continuation of research into industrialised house-building, based on my licentiate work and industrial experience, but with a stronger focus on strategic dimensions and how industrialised house-building affects companies. During my research project I had the opportunity to spend four months as a visiting researcher at Stanford University in California. During my stay I visited and studied several companies that had recently started to apply industrialised house-building processes. This gave me valuable material and knowledge about how these companies were structured and organized, and hence indications of the structural and organizational requirements for success, in a market context that differed in several respect from Swedish contexts. At Stanford, I also organized and gave a course on industrialised house-building for graduate students.

Throughout my doctoral studies, I have collaborated with colleagues at Luleå University of Technology and Linköping University of Technology. By collaborating with leading researchers at these universities I have tested my ideas and gained further valuable knowledge and assistance. As an industry-associated doctoral student I was able to join the research programme ProViking, a programme focused on research on product and production development within the manufacturing industry. I participated in courses and research seminars that provided more valuable knowledge and insights. At the department of building and environmental engineering at Lund University, I have collaborated with

research colleagues within the fields of structural engineering, industrialised construction, building information modelling, and architecture. This has reinforced my knowledge of both technology and processes applied in construction, as well as providing opportunities for me to share ideas and discuss my own research with fellow PhD students and senior researchers engaged in related scientific fields.

My scope of interest is schematically illustrated in Figure 1, showing how my interests have evolved over time, leading me to new knowledge and insights.

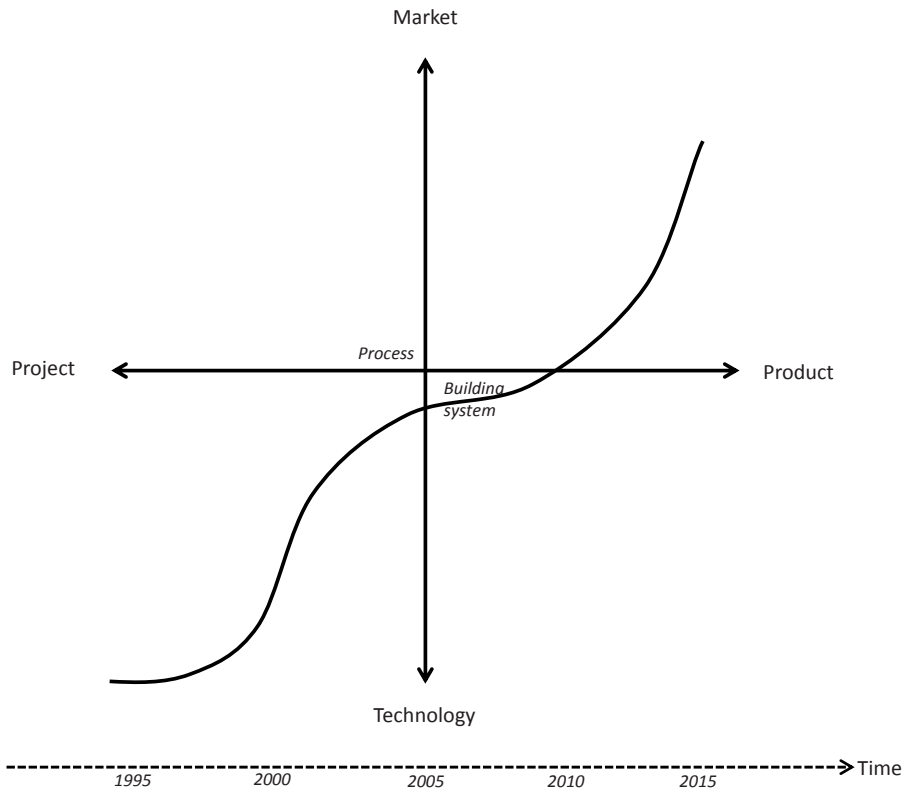


Figure 1 The author's research interest and main focus over time.

My experience of work in both academia and industry has naturally affected me as a researcher, and helped me formulate the aims and scope of the research. However, it has also increased the risk for bias, by potentially encouraging thoughts that I already knew the answers to the questions posed and could already explain studied phenomena, which could have impaired my attention to nuances and contrasts in my studies (Voss *et al*., 2002). Both my supervisors and I have been aware of this risk, discussed it throughout my doctoral studies, and

considered it in the design and analysis of case studies. All three appended research articles are co-authored, and I have maintained a high level of transparency concerning data collection methods, results and analyses, in order to minimize the risk for bias.

Research strategy

Industry-related research is complex and needs to address diverse inter-related and co-existing factors, such as technology, process, operations management, market and organizational issues (Robson, 2002). This necessitates use of research methods capable of handling such complexity.

The field of industrialised house-building is characterised by its complexity and influences from various theoretical fields, which is presented in Article I. There is no specific theory of the phenomenon *per se*, instead there are numerous related theoretical fields. At the same time, industrialised house-building is emerging strongly in the construction and house-building industry with various applications and strategies, thereby influencing the understanding and apprehension of the field. Hence, there is a need to describe and characterise industrialised house-building from a holistic perspective in order to strengthen its theoretical foundations. It is also crucial to apply a suitable research strategy and design in order to handle the complexity of the field, including the theoretical and scholarly developments in parallel with the impact of the industry's development.

Qualitative research is described as suitable for studying phenomena in their natural settings, particularly when it is important to understand in-depth processes within industries or organizations, when poorly understood systems and phenomena need to be explored and described, and when the purpose is to make sense of and interpret the studied phenomena (Miles and Huberman, 1994). Further, qualitative research enables broad and rich descriptions and holds possibilities to capture ideas and meanings of individuals within the studied context (Denzin and Lincoln, 2011). Another important aspect of qualitative research, in my opinion, is its likelihood to contribute to the development of new empirically supported ideas and theories (Eisenhardt, 1989), along with its possibility to provide research results that are also relevant and useful for practitioners (Denzin and Lincoln, 2011).

Case study research

Case study is a commonly applied methodological choice in qualitative research, which typically involves various data collection methods to enable descriptions and interpretations of complex phenomena studied in real-life contexts (Yin, 2003). The possibility to combine different methods for collecting empirical data is an important strength of case study research since it enables comparisons and triangulation of data, which can substantially improve validity (Stake, 1995). As a research strategy case study gives the researcher opportunities for deep study of contemporary phenomenon within their contexts, which distinguishes this strategy from others, in which attempts are typically made to divorce phenomenon and context in order to focus on a controlled number of variables (Yin, 2003).

The purpose of this research is to contribute to the theoretical understanding of industrialised house-building from a conceptual and strategic perspective, which requires interaction with the industry and relevant actors to obtain the empirical data needed to describe and understand the complex focal phenomena, as described by Voss *et al*. (2002). Therefore, a strategic choice was to select an exploratory, qualitative research strategy for this research. Further, the necessity to couple the research to development of the industry, company operations and their strategies led to the strategic choice to gather empirical data through case study research.

In qualitative research generally, and case studies particularly, the researcher is the main tool for gathering and analysing information, as well as playing a key role as a human instrument for transferring data (Merriam, 1998). This sets high demands on the researcher's sensitivity to identify contextual aspects and variables that may be significant, such as situational aspects, participating persons and non-verbal messages (Lincoln and Guba, 1990).

According to Voss *et al*. (2002), case study research is suitable for studies of emerging practices and operations management in efforts to develop theory and new ideas. This view is shared by Denzin and Lincoln (2011), who emphasise that the opportunities to combine multiple methods for gathering empirical material are beneficial for an in-depth understanding of the studied phenomena, as well as enabling triangulation of data.

Case research on operations and organizations enriches not only theory, but also the researchers themselves, who benefit from exposure to real-life contexts when conducting research in the field. By meeting and interacting with people with deep skills and insights, at all levels of organizations, researchers personally benefit and learn things from the research beyond the factual results. Furthermore, the individuals and organizations involved in case study research benefit from interaction with the researchers (Voss *et al*., 2002).

Three main types of case studies are described by Stake (1995): intrinsic, instrumental and collective. The purpose of the research determines which type of case study is most suitable, and whether a single or multiple case study is most appropriate (Merriam, 1998). It is also highly important to carefully choose an appropriate case (or cases) to include, with respect to the research's purpose along with assessments whether the case is likely to generate valuable empirical data (Stake, 1995).

Research quality

Qualitative and case study research methods are sometimes criticised for being unsuitable for building theory and for generalisations based on cases being unreliable. Flyvbjerg (2006), however, responded to such criticism and presented and discussed opposite findings. Nevertheless, the debate highlights the importance of clearly describing efforts to ensure research quality, which is essential for all scientific work. A crucial aspect of quality, validity, in case study research is discussed by (among others) Yin (2003), who distinguishes between construct validity (establishment of appropriate operational measures), internal validity (identification of causal relationships) and external validity (generalizability of the findings). Further, reliability is also a fundamental issue to consider when planning research activities. This means that the researcher must determine to what extent the case study's operations are repeatable and thus possible for other researchers to conduct with the same results (Yin, 2003).

Research design

This research design was guided by the purpose and research questions presented above, following the rationale presented in the Introduction, seeking to acquire a holistic understanding of industrialised house-building, then examining in detail strategic orientations and business models. An important step for structuring and explaining complex theoretical phenomenon is to establish a conceptual framework that can describe key factors, variables, relations and constructs - graphically or in narrative form - as described by Voss *et al*. (2002). This helps the researcher to elucidate the limitations and focus of the research. Ideally a conceptual framework should also be rooted in relevant literature, which both strengthens the framework and assists comparisons of findings with results of previous studies (a form of triangulation).

These reasons led to the decision to review literature related to industrialised house-building, in order to establish literature-based foundations. The review was expected to identify the characteristics and constructs required for describing industrialised house-building holistically. Further, a case study was decided to complement the literature review in order to contribute with information about companies' development and applications of industrialised house-building.

During the research undertaken as part of the licentiate research project, a multiple case-study of three Swedish companies (applying different industrialised house-building approaches) was conducted and presented. That research also included a literature review, although it was limited due to the poorly developed nature of the field at the time. Nevertheless, this led to a proposed conceptual framework for industrialised house-building, presented in Lessing (2006).

This conceptual framework provided an excellent starting point for the further literature review and case studies in this research, and prompted the first research question posed in this thesis (RQ 1). The opportunity was to add new theoretical dimensions to the framework, thus contributing to the theoretical compilation of knowledge regarding industrialised house-building. This research design is illustrated in Figure 2.

Case study I was a continuation of the examination of the three companies studied during the licentiate research project. These three companies had continued to develop their industrialised house-building activities, which had been monitored regularly between 2005 and 2013. The companies also showed differences in their applications, which suited the purpose, hence they were deemed suitable for this case study (Stake, 1995). The results from case study I and the literature review are presented and analysed in Research article I.

Case study I and the literature review provided deep insights into how industrialised house-building had developed and confirmed that additional constructs, including strategic perspectives on industrialised house building companies and their business models, were highly important for increasing understanding of such companies. This led to formulation of research questions two (RQ 2) and three (RQ 3) posed in this thesis. Business models were chosen as the unit of analysis due to their holistic, descriptive nature (for further details see the frame of reference section). In order to establish a theoretical foundation for the strategic and business model attention, a literature study was conducted, screening this theoretic field along with an increased focus on product-orientation and related theories.

Two case studies were conducted to gather empirical data to meet the research objectives and answer the research questions.

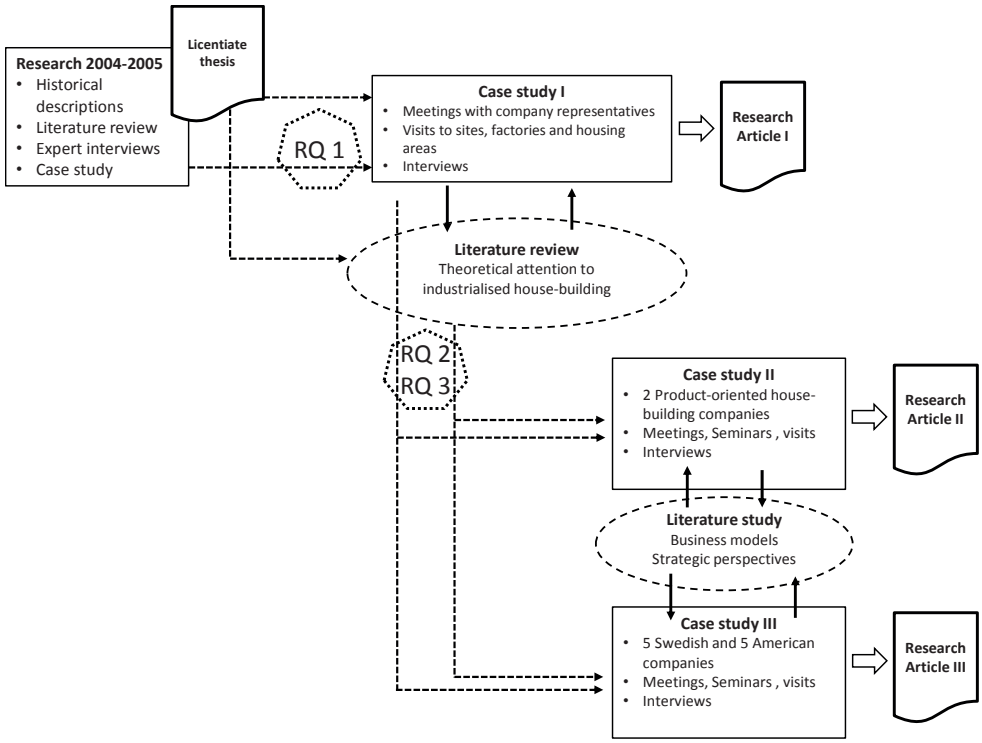


Figure 2 Schematic illustration of the research design.

It was decided to include two well-known and highly regarded Swedish product-oriented house-building companies in case study II. These were essentially the only two companies in Sweden that had adopted this category of business model, with a case history extending beyond 2-3 years, and thus met requirements for such research (Stake, 1995). This study had a narrow scope: to identify, describe and analyse the business models of product-oriented house-building companies, as a specialised variant of industrialised house-building companies. The results from case study II, complemented with the literature study, are presented and analysed in Research article II.

Case study III was designed to include 10 companies characterised as industrialised house-building companies acting in two different markets, in Sweden and the USA. The companies were included in the study in order to provide an in-depth view of industrialization approaches and business models, deliberately chosen because they had differing histories, starting points and market surroundings (Stake, 1995). It should be noted that two of the studied companies focus on building schools, not residential buildings, but were included because they were deemed sources of valuable empirical information regarding business

models and innovative operational platforms. The difference between these companies' product scope and house-building companies', are considered of minor importance for the purpose of this research. One might argue that companies with different product scope relate differently to the constructs of industrialised house-building and business models, however, these differences are assessed to be minor. It is rather seen as an opportunity by the exploration of a variety of business models. The two companies studied in case study II, are included also in this case study due their relevance and specialised business models. The results from case study III, complemented with the literature study are presented and analysed in Research article III.

Theoretical and empirical contributions

This research has contributed to the theoretical build-up of industrialised house-building, initially through the literature review and case study I, as discussed and analysed in Research article I. This research has contributed to the theoretical build-up of industrialised house-building, initially through the literature review and case study I, as discussed and analysed in Research article I. The conceptual framework describing industrialised house-building was stated to reflect both the scientific attention and how industrialised house-building is applied in the industry. However, it was also concluded that the conceptual framework needs to be complemented with a strategic dimension, including business models, strategy and organisation, as they are crucial aspects to consider and integrate in the further development of the field.

Case studies I and III, reinforced by the literature study, describe a variety of industrialised house-building companies' strategic orientations and business models. The observations are analysed and used to extend the theory of industrialised house-building in a strategic perspective. In addition, the conceptual business model framework originally developed by Brege *et al*. (2014) is complemented with theoretical contributions concerning business model starting points (product or production orientation) and the strategic impacts of different product approaches.

Research process

The research design section outlined the main parts of this research and how they are related to each other. This section describes in detail the execution of the research activities.

Literature review (industrialised house-building)

Literature on industrialised house-building was reviewed to reinforce the theoretical foundations for the further studies planned. Literature was searched using keywords, authors and journals, based on findings from the earlier licentiate work, presented in Lessing (2006), extended with additional propositions found in literature focusing on various orientations and characterizations of industrialised house-building and closely related themes. After the search phase, the publications were studied and the main orientation mentioned in their analysis, discussion and/or conclusion sections was documented with keywords.

Case study I

This case study was executed over a period of nine years, from 2005 to 2013 and was divided into three main parts. The first part was executed in 2005 and included observations and meetings at building sites, factories and housing areas on five to seven occasions per company. This was followed by three semi-structured interviews with key representatives (business manager, manufacturing manager, site manager) in each of the three companies, along with studies of documents describing the companies, their technology and processes. This first part provided deep insights into the companies' implementation of industrialised house-building. The second part, between 2006 and 2012, involved numerous company visits and research seminars (in which the company's executive managers participated), along with further studies of documents, providing continuous updates about the companies' progress. The third part was executed in 2013 when the companies were re-visited and one semi-structured interview was conducted per company, providing a structured and detailed dataset concerning the companies' development. These interviews were made with the CEO, product manager and business manager in respective company.

Analysis of literature review and case study I

The literature review resulted in a matrix with a large number of rows, presenting the keywords and scientific attention of the studied publications. These keywords and the publications' orientations were analysed and structured into the different constructs deducted from literature and presented chronologically sorted, based on themes and main contributions and thereby proposing complementing constructs to the conceptual framework from Lessing (2006). Thus a more comprehensive conceptual framework, presenting a system of constructs characterizing industrialised house-building was proposed. The case study's longitudinal execution and its multiple sources of information enabled the study's construct validity, further increased by the fact that the material was approved by company representatives. The theory refinement approach (Voss *et al*., 2002) in this study examines this developed proposition by contrasting it to the findings of the case study.

The acquired data were first structured and coded into broad categories, then refined into constructs. The case study data were analysed by comparing the coded data with the constructs of the conceptual framework, to detect fit - or lack of fit - in terms of how the studied companies changed their use of industrialised house-building, thereby securing internal validity (Yin, 2003).

Literature study (strategy, business models)

A literature study focused on strategy and business models was executed in three steps. First, a series of literature seminars were conducted, with six participating researchers. A list of 50 publications covering strategy and business models was established by three professors with extensive experience and knowledge of the field of business strategy and business models. Each participant was assigned to read 10 of these publications, with some overlap. Each participant presented his/her publications to the others during two seminars, providing a holistic view of the theoretical field. In the second step each participant chose another seven publications to study further, and sought individually for complementary literature (via key word and author searches), based on the previous presentations, and again presented findings related to industrialised house-building to the others. This efficiently provided a holistic view of relevant literature and in-depth knowledge of publications covering strategy and business models related to industrialised house-building. In the third step literature covering business models and strategic perspectives was sought, along with product-orientation related to industrialised house-building. Again the compiled literature was presented within the group of researchers. This literature study efficiently provided an overview, followed by in-

depth studies of relevant literature that facilitated the design of case studies II and III. In Research articles II and III the literature study is presented in the frame of reference sections.

Case study II

This case study was executed over 18 months, from 2013 to 2015, and the work was divided into four phases. The first phase aimed at providing an overview of the two focal companies, through individual meetings with company representatives, seminars and visits to building sites, factories and housing areas. The aim of the second phase was to acquire more detailed descriptions of the companies, and included six semi-structured interviews with executive managers (CEO, market manager and product respective operations manager. The third phase included studies of documents such as marketing material, internal training documents and web pages, contributing to a deeper understanding of the companies. During the fourth phase the empirical material was structured and coded according to the business model framework of Brege *et al*. (2014), which provided an overview that supported comparisons, analyses and conclusions. The execution of the case study is presented in Research article II and summarised in Table 1 below.

Case study III

This case study was executed over 24 months, from 2013 to 2015, and the work followed a pattern divided into five steps, repeated for all companies. The first step involved one to three individual meetings with CEO, product manager, operations manager or market manager, of the companies to obtain an overview of them. The second step aimed at getting a deeper and more detailed understanding of the companies' offerings, production methods and organizations, and included meetings with staff during visits to offices, factories, and building sites. Executive managers (CEOs, product managers, operations managers) of each company (except one) also participated in individual seminars, in which the companies' management teams presented their concepts, and the presentations were followed by discussions and conversations. The data collected during steps 1 and 2 were structured and coded using the framework presented in Lessing (2006). The third phase included studies of documents such as marketing material, internal training documents and web pages, and contributed to a deeper understanding of the companies. The fourth step involved individual, semi-structured interviews with 1-3 executive managers of each company, providing more detailed descriptions of the companies' business models. The fifth step included coding and structuring all

data according to the business model framework of Brege *et al*. (2014) to obtain an overview for comparisons and analyses. The execution of case study III is thoroughly described in research article III, and summarised in Table 1 below.

Analysis of case study II and III

Multiple sources of information were used in both of these case studies to enable triangulation and hence enhance construct validity (Yin, 2003), which was also increased by the structured research design (see Figure 2). Further, internal validity (internal cross-study logic) was bolstered by using the business model framework of (Brege *et al.*, 2014), which has already been used and found relevant in other studies, in both of the case studies. Concerning external validity and generalisations, it is crucial to be cautious. Nevertheless, the discussions of product- and production-oriented companies are judged to include potential for generalisations. Reliability was strengthened by meeting and interviewing the same people on several occasions, in efforts to compensate for the inability to repeat a case study, since the components of any case (people, situations and relations) change over time (Stake, 1995).

The analyses are of a qualitative nature, considering different mechanisms for fit between business model elements and strategic orientations of the companies along with the balance in mass-customization between customer demand in a specific market segment and flexibility in the product platform. The analyses of both case studies 2 and 3 have contributed to the refinement of business model theory and understanding of strategic aspects of industrialised house-building.

Table 1 The main activities in this research.

	Main activity	Contribution	Contribution to research quality
Literature review	Review of more than 45 publications related to industrialised house-building. Summarised in a matrix highlighting scientific attention of each publication.	Contributes to the theory refinement and build-up of the conceptual framework for industrialised house-building.	Construct validity and internal validity.
Case study I	Three companies were studied over a nine year period. In total this included more than 30 visits and meetings at building sites, factories and offices, 12 semi-structured interviews with executive managers, 10 seminars. Complemented with observations and document studies.	Contributes with empirical data and descriptions of companies' longitudinal development of industrialised house-building.	Construct, internal and external validity, along with reliablity.
Literature study	Literature seminars. Overview of 50 publications within strategy and business models. In-depth study of 25 publications on strategy, business models and product-orientation.	Contributes to the theory refinement and build-up of the conceptual framework forbusiness models and strategiec perspectives.	Construct validity and internal validity.
Case study II	Two companies were studied during 18 months. This included 6 meetings, 2 seminars, 6 visits at factories, building sites, and housing areas. 6 semi-structured interviews with CEO, market manager and production manager. Observations and document studies.	Contributes with in-depth descriptions of two product-oriented companies' business models and strategic perspectives.	Construct, internal and external validity, along with reliablity.
Case study III	Ten companies were studied during two years. This included 22 meetings, 9 seminars, 21 visits at factories, building sites and housing areas. 16 semi-structured interviews with CEO's, product managers and production managers.Observations and document studies.	Contributes with in-depth descriptions of ten industrialised house-building companies' business models, strategic perspectives and enables comparisons between different market surroundings.	Construct, internal and external validity, along with reliablity.

Theoretical frame of reference

Industrialisation in a historic review

Until the mid-1800s the building industry was not industrialised. Buildings were built with craft methods and locally produced materials, and knowledge was transferred from generation to generation (Cornell, 1970). One early step towards industrialisation of house-building, taken in Great Britain during the 1830s, was the introduction of "Manning Cottages", small prefabricated cottages that were shipped to Great Britain's colonies, to serve as homes for colonizers (Davies, 2005). In Sweden, similar initiatives were taken at the same time, for example by the company Siwers & Wennberg, which produced and exported buildings for people emigrating to California (Peyronson, 1995). In the USA, the company Sears Roebuck became the largest producer of prefabricated houses in the early 1900s, by introducing innovative methods for house-building. The company presented a portfolio of house models in catalogues, and complete kits of material and pre-cut parts along with detailed assembly instructions were shipped to building sites throughout the country (Davies, 2005). A similar concept was introduced in 1907 in Sweden, by the company Fogelfors Bruk, the first Swedish company offering series of predesigned and prefabricated houses, for the domestic and European markets (Peyronson, 1995).

In the 1920s important efforts were made towards standardization of building materials and building design. In 1922 the Swedish governmental building authorities published a collection of drawings for single and double family houses with small apartments, which contributed to dissemination of knowledge and facilitated house-building based on these specifications (Björk *et al*., 2009). Furthermore, throughout Europe architects associated with the modernism movement, such as Le Corbusier, Walter Gropius and Konrad Wachsmann, introduced radical new architecture, design and production ideas (Cornell, 1970), and large-scale building projects were undertaken based on building systems and utilization of prefabrication (Davies, 2005).

During the 1940s and 1950s there was a great need for new apartments in Sweden, as in many other countries in Europe after World War II. Partly for this reason, during the 1950s the building industry started to transform from a craft-based

industry to a more automated and technologically developed industry (Cornell, 1970). In Sweden, the cooperative housing organization HSB encouraged homebuilding by offering packages with pre-defined drawings and instructions for a kit of parts produced by the Swedish housing manufacturer Borohus (Engfors, 1987) (see Figure 3).

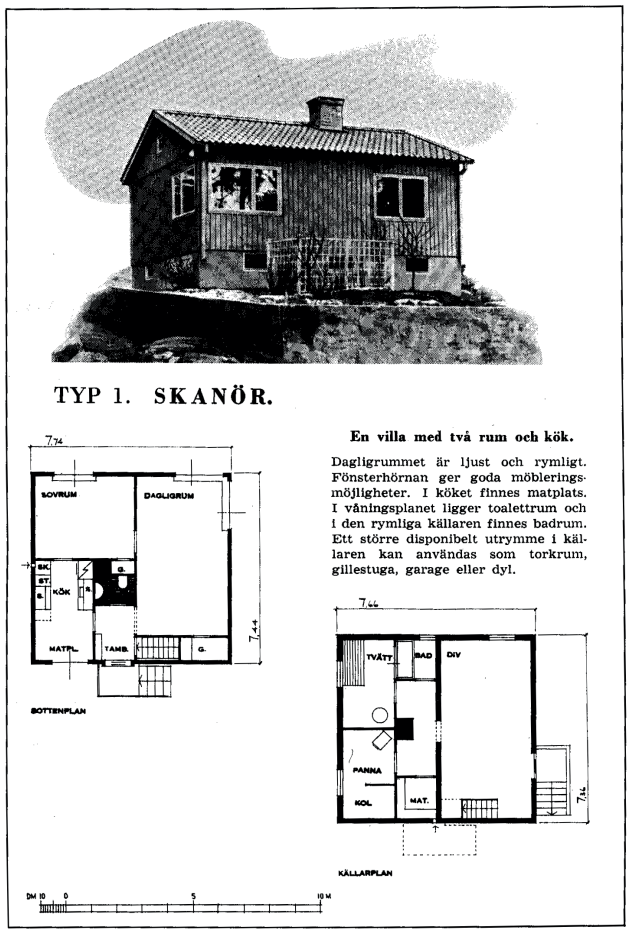


Figure 3 Marketing material from Borohus 1942, describing a standardized house (Engfors, 1987).

In 1964 the Swedish government introduced a programme to increase housebuilding, with the goal to build 100 000 apartments per year over the following 10 years and hence called the Million Homes Programme (Hall and Vidén, 2005). Intense development of the building industry followed, including the emergence of building systems with pre-defined solutions for complete residential buildings,

prefabrication techniques, and mechanization with innovations such as tower cranes, elevators and other machinery (cf. Marmstål and Nordberg, 1992, Skarne, 1987).

The dominating industrial principle in other manufacturing industries at that time was mass production, characterized by large series, technological standardization, and limited customization and variation (Womack *et al*., 1990). These principles were studied and adjusted to the peculiarities of construction then introduced and applied in construction (CIB, 1965). Innovations that were developed, introduced and applied at large scale in housing production included solutions for structural elements, roof structures, service installations and prefabricated modules, with complete kitchen and bathrooms for example (cf. Byggforskningsrådet, 1975, Deeson, 1967). Although the development was significant during this period it is important to note that industrialised house-building represented only a limited proportion of the industry and traditional, project-oriented methods and processes dominated the industry.

Figure 4 Assembly of prefabricated wall elements in a house-building project in the Million Homes Programme (Marmstål and Nordberg, 1992).

The large-scale production of apartment houses decreased abruptly in the early 1970s due to a surplus of apartments available on the market. Furthermore, the large-scale housing areas were criticised for being socially and technically poor. This led to a sudden change in demand and radical structural changes in the house-building industry. Much of the technology and production systems that had been developed ceased to be used since they required large volumes to be competitive and profitable (Adler, 2005).

Figure 5 Factory production of volume elements including a complete kitchen, bathroom and service installations, around 1960 (Marmstål and Nordberg, 1992).

The production of single-family houses in Sweden reached historically high volumes (40 000 houses annually) during the 1970s (Gabrielson and Ringmar, 1970). This part of the building industry followed the industrial tradition initiated in the 1800s, utilizing extensive prefabrication in factories. Most of the companies originated from the saw-mill industry, hence applying industrial principles and methods for housing production was a relatively obvious extension of previous business (Runberger and Gunterberg, 2006). The production of single-family houses did not decrease as abruptly as apartment building production, many of the companies involved could continue utilizing industrialised methods and processes, and many of these companies are still commercially active (www.tmf.se).

The contemporary development of industrialised house-building

In the early 2000s the Swedish house-building industry was thoroughly investigated, in response to problems caused by low levels of housing production and rising costs (Byggkostnadsdelegationen, 2000). Technology, production methods, working methods, collaboration, organization, supply chain management etc., were identified as important areas for the industry to develop in order to cope with problems concerning quality, cost, working conditions and competition (Byggkostnadsdelegationen, 2000, Byggkommisionen, 2002). Similar investigations a few years earlier in the UK had identified many similar obstacles (Egan, 1998). The problems encountered in the construction industry have been widely reported (Gann and Salter, 2000, Cox and Ireland, 2002, Gosling and Naim, 2009)

Industrialisation of construction and house-building was advocated in both governmental and industry investigations, pointing at positive developments in other more industrialised industries (Egan, 1998, Byggkommisionen, 2002, Industrifakta, 2006). However, the understanding of industrialisation was meagre, based merely on historical descriptions and, hence, needed to be enhanced and updated to reflect contemporary conditions (Lessing, 2006).

Industrialised house-building – a comprehensive view

An early contribution to understanding of industrialised house-building was presented by Gann (1996), describing Japanese house-building companies as controlling the entire production system. These companies were portrayed as utilizing systematized technical solutions, and executing production in highly automated factories. Several authors continued to explore such integrated production systems (Crowley, 1998, Barlow, 1999, Barlow *et al*., 2003, Roy *et al*., 2003), showing that innovation and development were required in several areas of the house-building process, such as logistics and supply chain partnering, long-term relations with suppliers, and support by integrated IT-systems, in order to achieve an integrated production system.

The production principles were described as being similar to those of the automotive industry, commonly referred to as Lean Production (Gann, 1996). The essentials of Lean Production are: elimination of waste, continuous improvements, close collaboration within the company and throughout the supply chain, focus on

the customer, and stable and standardised processes, integrated in a production system (Womack *et al*., 1990, Liker, 2004).

A lesson from the Lean Production paradigm (Womack *et al*., 1990) and the Toyota Production System (Liker, 2004) is the strength of having a clear focus on the customer, along with a thoroughly focused structure and integration of the design and production processes together with the supply chain, in order to deliver what the customers want, with the right quality, at the right price and right time. Another notable feature of the paradigm is a culture that constantly seeks to eliminate waste and increase process efficiency, with the assistance of tools, appropriate organizational structure and supportive management.

Studies of Lean principles applied in construction contributed to an understanding of industrialised house-building, characterised by integration and control of technical, process, organisational and production-related solutions and activities (Höök, 2006, Björnfot and Stehn, 2007, Lessing, 2006). Similarly, Nadim and Goulding (2011) investigated industrialisation of the European construction industry and concluded that five patterns (People, Technology, Process, Product and Market) must be integrated to increase the uptake of industrialisation. Organisational requirements for industrialised house-building companies were investigated by Unger (2006) who emphasised the importance of an organisational structure coherent with production and business strategies. This view was shared by Gerth (2008), who demonstrated similarities between a process-oriented industrialised house-building company and a manufacturing company. Gerth (2013) later proposed organisational building blocks for industrialised house-building companies, based on their integrated capabilities and a strategy for information management.

Alternatives to site-based production

Developing and applying alternatives to site-based production is closely associated with industrialisation, not least due to historical descriptions of industrialisation. Prefabrication methods and approaches have been thoroughly investigated. Gibb (2001) introduced the concept Standardisation and Pre-assembly (S&P), covering a range from components to modular buildings, and (thus) illustrating the variety in prefabrication methods. According to (Gibb and Isack, 2003) pre-assembly has considerable potential in construction projects as it is time- and cost-efficient, yielding improvements in quality and productivity. However, their approach has a more narrow production- and project-oriented scope, based on the traditional construction process, in contrast to the approach adopted by, for example Gann (1996), Roy *et al.* (2003), Barlow *et al.* (2003), as reported above, who describe

complete, integrated production systems, showing many differences from traditional construction.

Historical attempts to implement industrialisation in the construction industry have been criticized for over-emphasizing production aspects, creating large-scale housing areas with low customer orientation (Hall and Vidén, 2005). Mass customisation, which combines effective processes and methods with customisation, provides new perspectives on how alternative production processes, standardised technology and off-site production could be utilized to produce customised buildings in effective processes (Barlow, 1999, Barlow and Ozaki, 2003). Winch (2003) introduced the concept of production strategy into construction literature, based on the customer order decoupling point idea utilised in manufacturing, as previously presented by Sackett *et al.* (1997). This made an important contribution to the understanding that different production systems suit different kinds of construction and place specific requirements on the companies applying them.

Process orientation and platforms for increased continuity

Process-orientation in industrialised house-building companies is frequently reported (cf. Jansson, 2010, Söderholm, 2010, Malmgren *et al.*, 2011), emphasizing the need for integrating the design, planning and production processes with the supply chain. Such process integration is required to achieve stable, continuous processes (Sohlenius, 2006, Erikshammar, 2011), that can be continuously improved, based on performance measurements and experience from previous execution (Meiling *et al*., 2014). The importance of integrating design processes with manufacturing and site work is also widely reported (cf. Blismas *et al.*, 2006, Pan *et al.*, 2008, Jansson *et al.*, 2008), illustrating how integrated processes contribute to improved performance. There is, however, a clear difference between project-unique design (Blismas *et al.*, 2006, Goodier and Gibb, 2007) and design based on predefined solutions structured in platforms (Jensen, 2010). Project-unique process integration lacks the component of organisational and technical platform continuity over time and between projects that is required for continuous improvements and systematic management of knowledge.

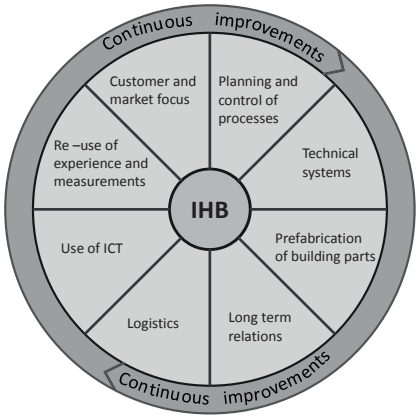
In a process-oriented value chain, long-term relations between design consultants or capabilities and the building company are common (Jansson *et al*., 2008). Furthermore, integration between purchasing, logistics and production, between and within companies, is reportedly important for achieving efficient supply chains (Bildsten *et al.*, 2011). This also allows joint product and system development, which enables reductions in delivery time and quality variations (Erikshammar, 2011).

Technical platforms play crucial roles in the development of industrialised house-building. By developing building systems with standardised solutions, buildings can be offered based on rigorously tested and robust technology (Björnfot and Stehn, 2007). However, a platform needs to be thoroughly structured and documented, as well as continuously improved (Johnsson *et al.*, 2007, Persson *et al.*, 2009, Söderholm, 2010), in order to serve as a robust backbone for processes and technical information and methods (Johnsson, 2011). Critical components include adequate information systems to handle the complexity of platforms, and support their use throughout design and configuration, manufacture, assembly, and site work (Jensen *et al*., 2009). Malmgren *et al*. (2011) introduced four information "views" (Customer, Engineering, Production and Assembly) enabled by an integrated IT system structuring all platform-related information.

Information technology has received much attention in construction literature, due to its importance in developing and re-engineering design and construction processes (cf. Eastman *et al.*, 2011, Fischer and Kunz, 2004). Most of this literature focuses on the traditional, project-oriented part of the industry. However, an early publication describing the benefits of integration and control of processes in combination with standardisation of technology was presented by (Crowley, 1998). Benefits of integrated IT-solutions are enhanced by close and long-term relations in the process (Naim and Barlow, 2003), as also stressed in a Swedish study emphasizing the importance of integrating the production system, facilitated by an information system (Olofsson *et al*., 2004).

A framework for industrialised house-building

Lessing (2006) was one of the first to acknowledge that industrialised house-building requires an integration of several constructs, where prefabrication and building systems are necessary means for production, but not sufficient to define or describe what industrialisation is. The conceptual framework emphasises that a set of eight characteristic areas, covering technical, process and organisational matters, need to be integrated and reinforced by continuous improvements (the ninth area) in order to establish industrialised house-building, with a strategic focus beyond the singular project, see Figure 6.



Planning and control of processes; Processes are thoroughly planned, structured and systematized throughout the organization
Developed technical systems; Technical solutions are developed and structured into systems
Prefabrication; Building parts are manufactured in facilities off-site.
Long-term relations; Participants in the processes are engaged on long-term basis
Logistics; The flow of materials and related information is integrated with design, production and building processes
Use of ICT; ICT-tools and –systems support structuring and managing information throughout all processes and technical systems
Re-use of experience and measurements; Performance measurements give information about process performance and reinforce best practice
Customer and market focus; Thorough knowledge about different customer segments' needs, priorities and expectations
Continuous improvements; Processes and systems are systematically improved

Figure 6 A framework with nine characteristic constructs that collectively constitute industrialised house-building (Lessing, 2006).

This was first published and presented in a conference article (Lessing *et al*., 2005), and extended in the licentiate thesis (Lessing, 2006). The framework also included a process model emphasizing that the execution of building projects must be supported by continuous development processes in which platforms for both technical solutions and processes are developed and managed. Experience from project execution is brought back to serve as input for further development (see Figure 7).

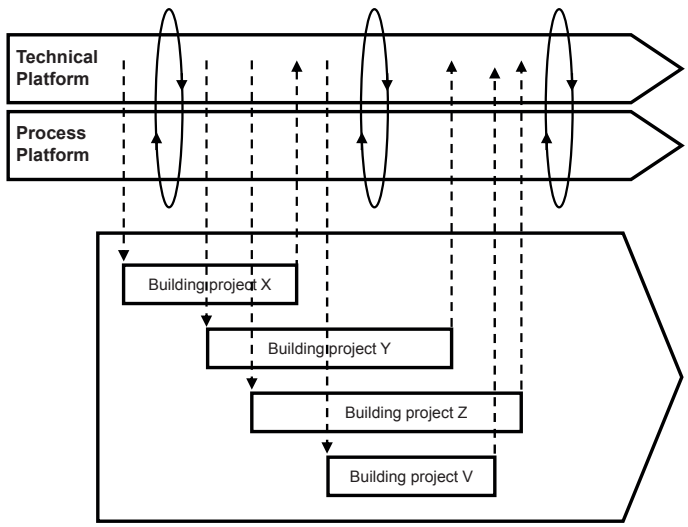


Figure 7 Development processes establish standardised solutions for technical and process solutions that support the execution of building projects, connected by a structured flow of information.

This framework provided a novel basis for further research in the field of industrialised house-building in Sweden (Apleberger *et al*., 2007, Stehn, 2013, Lidelöw *et al*., 2015). The novelty did not lie in the separate constructs of the framework, the need for many of them had already been noted in the literature (see above), and previously applied in various development attempts. Instead, the new aspect was the holistic integration of the parts, and placement in the context of a production system.

In the licentiate thesis, Lessing (2006) presented results from literature studies, case studies and interviews with industry experts, concluding that uses of product platforms and prefabrication were common first steps in the development of industrialised house-building, but adjustments in several other areas are also required to establish a viable concept for industrialised house-building. Johnsson (2012) conducted similar expert-interviews six years later with matching results. The industry perception was still (in 2012) that industrialised house-building is about establishing production systems for continuous use, the use of platforms is central, but also that several other aspects must be dealt with simultaneously. Johnsson also found that strategic orientations concerning market segments, production strategy and business models are crucial for further development.

This view was reinforced by the extensive literature review covering industrialised house-building and longitudinal case study of three Swedish industrialised house-building companies presented in Article I. In this article it was concluded that the framework from 2006 was useful for describing industrialised house-building, but required more attention to strategic aspects such as business models, production strategies and organisational issues connected to industrialised house-building.

Product-orientation of house-building

Product-orientation is an alternative to the traditional project-orientation that dominates the construction and house-building industry. In this context, a product is the result of a repetitive process, utilizing a platform or pre-developed structure of solutions for designing and producing the product (Meyer and Lehnerd, 1997). This contrasts to how buildings are commonly produced, as uniquely designed one-of-a-kind solutions executed by temporary teams in loosely coupled supply chains (Gann and Salter, 2000, Gosling and Naim, 2009). A product-oriented company specialises in offering a specific range of products. In order to achieve an effective process, product platforms allowing solutions to be repeated are established. Due to product offers' limitations in scope, production methods, technical solutions and sub-systems can be predefined and enable efficient end-product configuration (Ulrich and Eppinger, 2011).

Products, platforms and production systems

Products

Products are developed in product development processes, which are structured to systematically use knowledge from previous product development, production and supply chain, as well as from user experience (Ulrich and Eppinger, 2011). A product development process needs to continuously and systematically add knowledge in order to create foundations for reliable solutions. These foundations form the basis for new solutions and sub-systems that enable configuration of new end-products with improved functionality and design (Meyer and Lehnerd, 1997). Kennedy (2008) presented an illustrative model showing how a product development process is continuously built up by and complemented with new knowledge from specific product development projects, based on the company's knowledge value flow (see Figure 8).

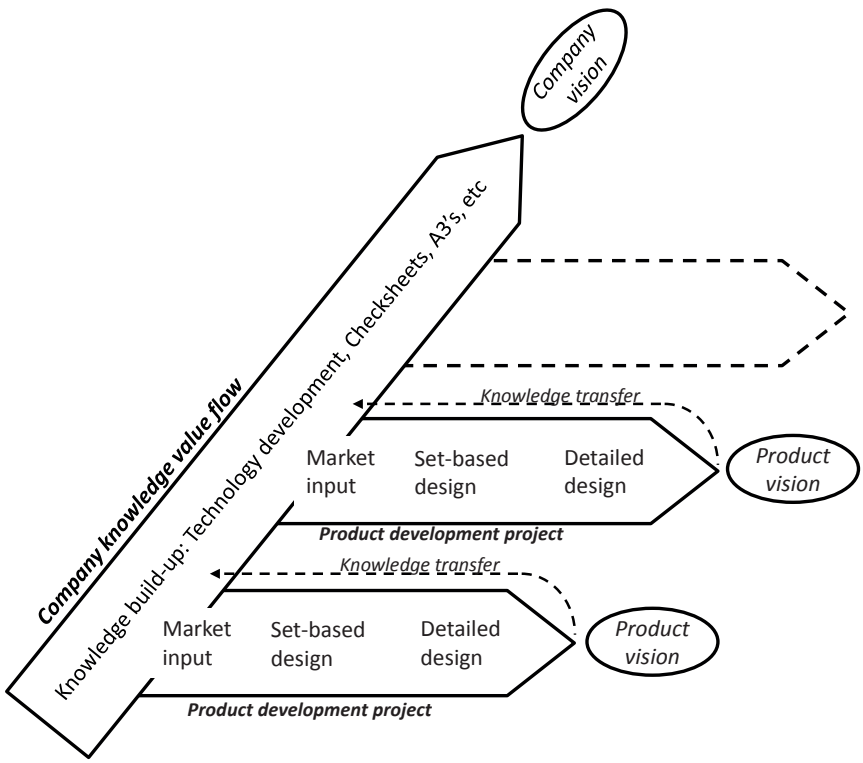


Figure 8 A product development process builds upon the company's knowledge value flow and systematically includes knowledge from previously executed project development projects. Adapted from Kennedy (2008).

Kennedy's (2008) model show similarities with Lessing's (2006) model for industrialised house-building, where knowledge from executed building projects systematically is fed back to the company's continuous development process. Such a product development process is based on a high degree of product predefinition in terms of well-known, preferred technical solutions that are complemented with new solutions developed to meet customer requirements and/or bring a new end-product to the market. Such product development processes also require input from sales, production and supply chain processes, and consequently benefit from integrated collaboration and long term relations throughout these processes, as described for instance by Winch (2003), Björnfot and Stehn (2007) and Jansson *et al*. (2014).

Platforms

The systematic structures of subsystems used for developing and producing derivative products are commonly called product platforms (Meyer and Lehnerd, 1997). Similarly, Robertson and Ulrich (1998) describe four assets that collectively constitute a product platform: Components, Processes, Knowledge, People and relationships. By executing design, production and supply of materials in cooperative, recurring processes by integrated teams engaged on a long-term basis, production systems are optimized for efficient product delivery. Product and platform development require a clear perception of the customers' needs, requirements and priorities in order to tailor attractive and competitive product concepts (Ulrich and Eppinger, 2011) aimed at certain market segments (Meyer and Lehnerd, 1997). The importance of integrating a customer focus in a product-oriented house-building process is also emphasized by Barlow and Ozaki (2003) and Barlow *et al*. (2003) as well as Lessing (2006). These authors stress that product-orientation requires long-term investments in platform development, production facilities and (hence) a clear understanding of the customers' priorities and needs is crucial in order to tailor viable product concepts.

Hvam *et al*. (2008) have contributed to the field of products and platforms by recognizing four levels of product predefinition in utilization of platforms, as shown in Figure 9. At the lowest level, traditional project-orientation (EtO), norms and standards are the main means of predefinition. The next level, Modify to Order (MtO), involves increased use of standardised technical solutions and strategically defined geometries and solutions for key components. The Configure to Order (CtO) level incorporates utilization of predefined parts, components and modules for configuring complete buildings, while the Select Variant (SV) level refers to pre-definition of complete buildings with minimal project-unique solutions. This comprehensive description of platform strategies shares similarities with the four production strategies and related design strategies presented by Winch (2003).

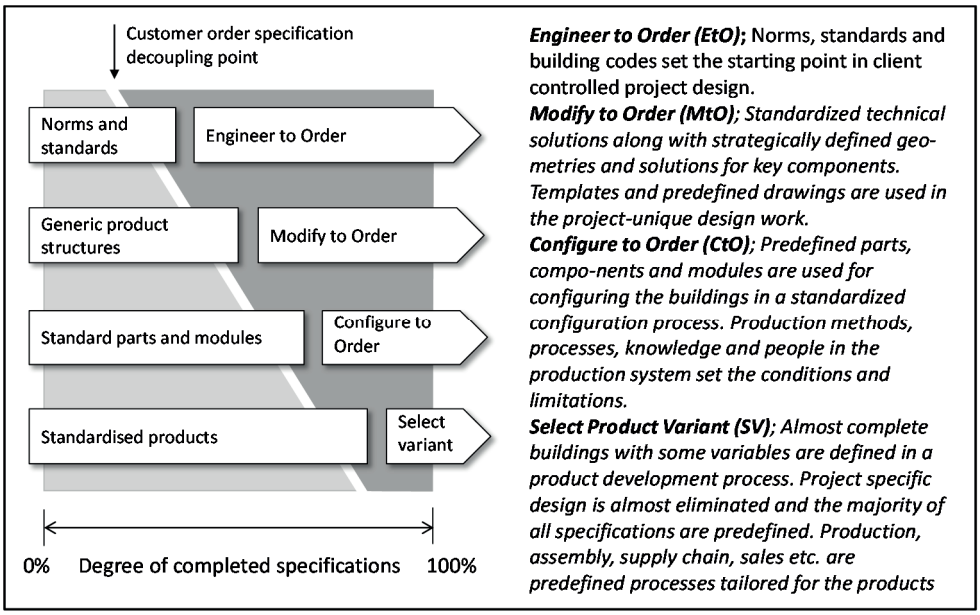


Figure 9 Four levels of product predefinition based on Hvam *et al*. (2008).

These levels can be seen as schematic illustrations of the variety in product strategies, where each level requires different set-ups of production systems and company structures depending on the company's offerings and way of executing them (Robertson and Ulrich, 1998).

Low levels of predefinition (EtO) and (MtO) give high flexibility in terms of the buildings that can be produced, but more project-specific solutions must be developed for each building. These set-ups reduce the predictability of the processes and ultimately the products produced. In contrast, high levels of predefinition (CtO) and (SV) limit the range of buildings that are offered and require more investments in platform development. However, such set-ups increase the predictability of the products and reduce the amount of project-specific work required (Jensen *et al*., 2015). These higher levels of predefinition, especially within the CtO-strategy, are characteristics of mass customization, a strategy for delivering customized products, but based on thoroughly standardised technical solutions, combined to generate unique end products (Barlow, 1999). High levels of predefinition are beneficial for the production and supply chain processes as well as the products, in terms of enabling the establishment of production systems for continuous production of selected products (Lidelöw *et al*., 2015).

Production system

A fundamental requirement for establishing product-oriented house-building is long-term and continuous utilisation of production systems, which enhances the stability of processes and knowledge in design, production and supply chains.A production system, in this context, is the structure of resources and capabilities that are integrated and organized for enabling repetitive production of a selected range of products (buildings). This includes design, technical systems, production facilities, knowledge, collaboration, supply chain activities and information management (cf. Liker, 2004, Ohno, 1988). Theoretical descriptions of production systems are rooted in systems theory, which describes how relations and interactions between various components of systems and sub-systems affect each other and whole systems (Rentzhog, 2000). This encompasses the production system's entire complexity in terms of structuring activities and operations involving planning, development, production, management, marketing as well integration with design and sales processes (Bellgran and Säfsten, 2009). The complex structure's over-arching aim is to produce products that are demanded by the customers, in a profitable manner (Rentzhog, 2000).

Product-orientation enables new possibilities for house-building companies

House-building companies adopting product-orientation enter a new line of business with potential to contribute to transformation of the house-building industry. As described above, product-orientation means increased control and predictability of the planning, design, and production processes related to industrialised house-building. This includes promising opportunities concerning the quality and customer value of the produced buildings. However, product-orientation holds further opportunities, in a long-term perspective. Other industries such as the shipbuilding, automotive and aerospace industries have an increasing focus on combining physical products with services throughout the products' lifecycles (Baines *et al*., 2007). Similarly, combining products and services could provide opportunities for industrialised house-building companies to expand their offerings, thereby emphasising their difference from traditional building companies.

Product Service Systems

A product can be described as being composed of a physical part, the tangible product that is manufactured and offered to the customers, and an intangible part consisting of various services that are offered to the customers (Tukker and Tischner, 2006). Structured offerings that systematically combine both tangible

and intangible products (services) are commonly called Product Service Systems (PSS).

This concept has been defined and described by several authors, e.g. (Mont, 2002, Manzini and Vezzoli, 2003, Tukker and Tischner, 2006), with small variations in definitions. They commonly state that a PSS is a systematic way of structuring a combination of tangible products, services and the networks needed to satisfy customer needs. The definition by Manzini and Vezolli (2003) emphasizes that such a system means a combination of physical products and services that affects the company's offerings and business scope:

> "A Product Service System is an innovation strategy, shifting the business focus from designing (and selling) physical products only, to designing (and selling) a system of products and services which are jointly capable of fulfilling specific client needs."

The balance between tangible and intangible elements in a PSS varies from case to case and can be dominated by product-orientation with complementary services or by services associated with a minimum of physical products, as illustrated in Figure 10 (Tukker & Tischner, 2004).

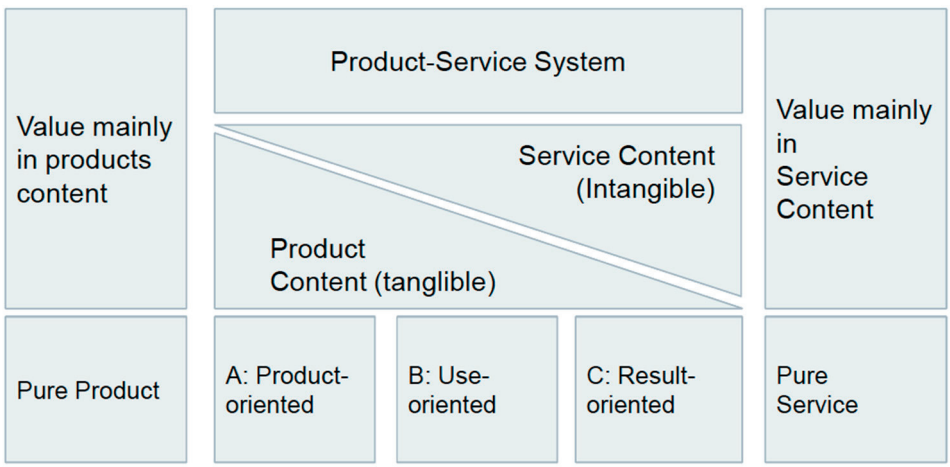


Figure 10 A Product Service System consists of tangible and intangible content, balanced according to the company's business model (Tukker & Tischner, 2004).

Baines *et al*. (2007) state that there are three main types of product-service-systems, with varying focus (product-oriented, use-oriented and result-oriented) as also shown in Figure 10.

The development of PSS has emerged rapidly and their importance for product-companies' business concepts as a means to reinforce customization is increasing (Mont, 2002). One important aspect of a product service-offer is that it initiates a

long-term relationship between the product-company and its customers, since the service-offer is extended throughout the life-cycle of the physical product (Manzini and Vezzoli, 2003). This introduces new tasks for the company to execute along with new revenue streams (Kindström, 2010). The long-term commitment also relates closely to sustainability, since the more sustainable the solutions are, the more is gained by the product-service provider in terms of low energy use, increased usage and reductions in maintenance and repair costs (Roy, 2000).

Product Service Systems for house-building

Product-Service-offerings have barely emerged in the house-building industry, probably due to the dominating project-orientation, and because product-oriented house-building companies are relatively recent market entrants. However, application of product-orientation in house-building provides new opportunities in terms of combining physical products (buildings, apartments or homes) with intangible services throughout their lifecycles.

There has been very little research on PSS applied in house-building or construction. However, some authors touch upon the topic and some examples have been mentioned. Brady *et al*. (2005) explore the opportunities and obstacles for applying "integrated solutions" in the construction industry, which are described as combinations of products and services that address customers' requirements throughout their lifecycle, and thus are conceptually similar to PSS. They state that a company aiming to "integrate solutions" needs to structure its business around repeatability in terms of both technical systems and services offered, as well as standardized processes. The authors conclude that a shift towards such innovative behaviour requires maturity in the company's product offering, a willingness to invest in the build-up of capabilities and a surrounding market that is open for these innovations (Brady *et al*., 2005). As illustrations of such offerings, Linner and Bock (2012) describe how some Japanese industrialised house-building companies' have developed service innovations as complements to their houses. Applying large-scale industrialisation concepts with thoroughly developed and integrated production systems, including advanced factory production, product platforms, integrated IT-systems and standardized processes, these companies were producing 4000 to 55000 homes per year in 2011. These companies benefit from their well-known products and processes to offer their customers extended warranties, in combination with services throughout the buildings' life. Upgrade services, renovation services, customizable energy platforms, personal assistance technologies, and re-customization are examples of services offered to the customers (Linner and Bock, 2012). The cited authors emphasize that these companies show more similarities to product industries than construction companies, which they say is crucial for the companies' PSS.

Research on the topic of product-service-systems applied on house-building or construction is very scarce. However some authors touch upon the topic and some examples can be found. Brady *et al.* (2005) explore the opportunities and obstacles for integrated solutions to be applied in the construction industry. "Integrated solutions" is described as a combination of products and services that address customers' requirements throughout the lifecycle, thus a similar concept as PSS. It is stated that a company aimed at integrated solutions need to structure their business around repeatability concerning both technical systems and services offered, as well as standardized processes. The authors conclude that a shift towards such innovative behaviour requires a maturity in the company's product offering, a willingness to invest in the build-up of capabilities and that the surrounding market is open for these innovations (Brady *et al.*, 2005). Linner and Bock (2012) describe how some Japanese industrialised house-building companies' have developed service innovations as complements to their houses. The companies apply large-scaled industrialisation concepts with thoroughly developed and integrated production systems, including advanced factory production, product platforms, integrated IT-systems and standardized processes, producing between 4000 and 55000 homes per year, in 2011. These companies benefit from their well-known products and processes to offer their customers extended warranties, in combination with services throughout the buildings life. Upgrade services, renovation services, customizable energy platforms, personal assistance technologies, and re-customization are examples of services offered to the customers (Linner and Bock, 2012). The authors emphasize that these companies show more similarities to product industries than construction companies, which is stated to be crucial for the companies' product service systems.

Business models and strategic perspectives

As discussed above, industrialised house-building is an integrated design and production process that needs to be developed and managed differently from traditional project-oriented building.Evaluations of companies applying alternative technology, production methods and processes have highlighted a lack of expected benefits in building projects (Blismas *et al*., 2006). However, uptake of Off-site construction in UK is slower than expected, as stated by Pan and Goodier (2012), and a possible reason for the slow uptake and fulfilment of expected benefits is that industrialisation has been treated as an operational or tactical, rather than strategic, matter.Companies applying industrialised house-building need to implement structures for managing a two-dimensional set-up with both continuous

processes for developing and managing the production system and its included sub-systems, along with the execution of building projects, as described by Lessing (2006). Goulding *et al*. (2014) also emphasize the need for industrialised house-building companies to establish alternative structures concerning utilization of technical solutions and systems, organization, processes and supply chains in order to achieve the benefits of industrialisation. Similarly, Brege *et al*. (2014) note the need for alternative structuring and utilization of technical systems, processes and supply chain collaboration and related investments, along with Gerth (2013), who emphasizes the need for suitable organizational structures for industrialised house-building companies. Such transformations of companies' operations, roles and offerings are consequently of strategic nature and need to be managed as such.

Business models are suitable constructs for strategic descriptions and analyses of the logic of companies and how they operate (Baden-Fuller and Morgan, 2010).Strategic choices and their consequences for companies are fundamental aspects of business model build-up, which highlight the importance of integrating their components, including aspects related to companies' offerings as well as market and operational aspects (Casadesus-Masanell and Ricart, 2010).

Business models

The concept of business models has attracted great interest since the early 2000s, initially due to the emergence of internet-related companies, which increased the need for clarifying the new business concepts they embraced (Zott *et al*., 2011). Business models have been used in three main ways: as descriptions of how enterprises work (Magretta, 2002), as architectures of business concepts (Teece, 2010), and as analytical tools to examine strengths and weaknesses of specific company cases (Amit and Zott, 2001, Chesbrough and Rosenbloom, 2002).

The business model concept can also be defined with varying focus and detail. For example, Osterwalder *et al*. (2005) presented a framework identifying four business domains (products, customer interface, infrastructure management, and financial aspects) divided into nine building blocks, which provides a frequently used tool for overviewing companies' business models in a structured way (see Table 2).

Table 2 A business model framework consisting of four main domains and nine building blocks (Osterwalder *et al*., 2005).

Pillar	Business model Building Block	Description
Product	Value Proposition	Gives an overall view of a company's bundle of products and services.
Customer interface	Target Customer	Describes the segments of customers a company wants to offer value to.
	Distribution Channel	Describes the various means of the company to get in touch with its customers.
	Relationship	Explains the kind of links a company establishes between itself and its different customer segments.
Infrastructure management	Value Configuration	Describes the arrangement of activities and resources.
	Core Competency	Outlines the competencies necessary to execute the company's business model.
	Partner Network	Portrays the network of cooperative agreements with other companies necessary to efficiently offer and commercialize value.
Financial aspects	Cost Structure	Sums up the monetary consequences of the means employed in the business model.
	Cost Model	Describes the way a company makes money through a variety of revenue flows.

A more general definition was presented by Baden-Fuller and Morgan (2010), stating that a business model explains the logic of the firm, the way it operates and how it creates value for its stakeholders.Casadesus-Masanell and Ricart (2010) argue that strategic choices and their consequences for various aspects of companies are fundamental components for constructing a business model, and that a good fit between a business model's components is essential. Mintzberg (1983) also emphasizes the importance of a good internal fit between the components, and between a business model holistically and its objectives, i.e. the market environment it acts within. The fit determines the business model's success, and can be evaluated by comparing the starting point with the business model's components' contribution to the objective.

Business models for industrialised house-building

As part of the consideration of opportunities for applying "integrated solutions" in the construction industry (as discussed in the PSS section above), Brady *et al*. (2005) also explored the opportunities to introduce associated business models. Integrated solutions share many similarities with industrialised house-building (as well as PSS), including continuity in technology, processes and relations, although

the integrated solutions concept also includes provisions of services throughout the product's life cycle. The cited authors state that transformations of strategies, positions in the value stream, capabilities, organizational structures, cultures and mindsets are required in order to introduce a business model for integrated solutions in the construction industry.

Research on business models for house-building and construction companies is scarce, as stated by Pan and Goodier (2012), who thoroughly reviewed research in the area, focusing on off-site construction. A literature review by Abuzeinab and Arif (2014) also concluded that the area is under-researched, and although interest in it is increasing there is a need to explore and clarify the business models of house-building companies applying alternative methods, in order to increase the up-take of such concepts.

This view is shared by Goulding *et al*. (2014), who highlight the need for new business models to accelerate change in the house-building sector. Such structural changes require new relationships, skills, technology, processes and ways of working in the house-building companies and connected supply chains. Industrialised house-building and the related concepts off-site construction and modern methods of construction have been mainly considered as technological solutions, rather than innovative business concepts, which explains their scarce exploration in a business context (Pan and Goodier, 2012). However, a stream of literature on business models connected to industrialised house-building is emerging, including contributions by Brege *et al*. (2014), Höök *et al*. (2015) and Lessing and Brege (2015a), which adopt the description of how enterprises work and analytic tool approaches to dissecting business models (discussed above).

Brege *et al*. (2014) presented the first evaluation of business models in the context of industrialised building. An important contribution was a business model framework tailored specifically to address this phenomenon, with three cornerstones (Operational platform, Market position and Offering) required for describing a house-building company's business model as an integrated concept (Figure 11).

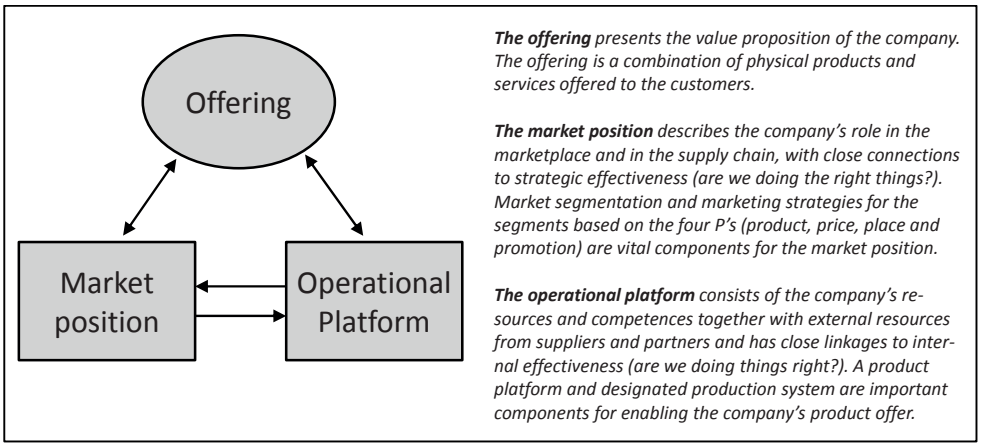


Figure 11 The business model framework for industrialised house-building developed by Brege *et al.* (2014).

Article II (Lessing and Brege, 2015a) extended the exploration of business models for industrialised house-building and presented results from a case study of two Swedish product-oriented house-building companies. The study revealed that a market-based, Outside-In perspective, as described by Porter (1996), was followed in the establishment of the companies' business models, allowing a successive build-up of the operational platform, which enabled cost-effective and viable business models.

Strategic perspectives

Strategy and business model are closely linked concepts and whether are distinct or overlap is basically a matter of definition. Hedman and Kalling (2003) argue that the business model concept is suitable for integrating disparate strategic perspectives, by including elements from strategy-related research into a generic business model description. One frequently used demarcation line is that strategy includes competition and focus upon competitive advantage, while business models put emphasis on creating customer value (Magretta, 2002). However, some researchers focus on other differences, for instance Seddon *et al*. (2004) view business models as abstractions of strategy, and Yip (2004) argues that a business model describes the strategic positioning of a company while the strategy more dynamically guides the company in a changing business landscape. In the model presented by Hedman and Kalling (2003), competition along with customers and suppliers are components that are included in the business model and affect its core elements: offering, activities and resources. Teece (2010) on the other hand claims that a business model is more generic than a strategy, and that a strategy

formulation is a more granular exercise than designing a business model. By coupling competitive strategic analysis and business model design a viable business model is crafted and protected from competitors (Teece, 2010). A study by Höök *et al*. (2015) shows that critical strategic incidents can (intentionally or unintentionally) trigger changes in business models and the management of a portfolio of business models. This follows the reasoning that "strategy" should be considered a factor that influences business models, rather than a construct of the models.

Regardless of the difference between the strategy and business model concepts, the two major strategic perspectives on "cause-effect" in formulation of strategies and business models are very relevant. Are business models basically developed outside-in or inside-out, two approaches that at least in theory (but less often in practice) seem fundamentally different? In a market-based, outside-in perspective to business model development market and customers' demands and needs are used as the starting points for formulation of the company's offers (Porter, 1996). The offers provide input to product development and set demands on production and supply chain resources for enabling the offer competitively (Porter, 1985). Teece (2010) describes the process in four steps: (1) segmenting the market, (2) creating a value proposition for each segment, (3) setting up the apparatus to deliver that value, and (4) figuring out isolating mechanisms to prevent the business model being undermined by competitors. Other important factors include trade-off considerations, i.e. decisions of what to leave aside, in order to keep a distinct line of strategy development and focus in the organization (Porter, 1996). In contrast, in a resource-based, inside-out perspective the organization's core competences and resources are used as the starting points for strategy formulation (Prahalad and Hamel, 1990). Offerings are shaped according to the company's resources, such as technological knowledge, employment of skilled personnel, trade contacts, machinery, efficient procedures, brand names etc. Further, market segments with demands for such offerings are sought, in order to establish business opportunities (Wernerfelt, 1984). As already mentioned, a fundamental requirement for this approach is the ability to exploit internal and external competences to deliver value creation and competitive advantage (Teece *et al*., 1997).

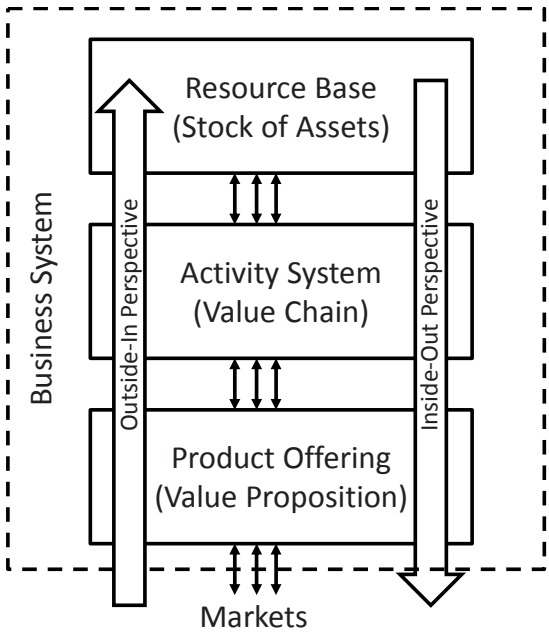


Figure 12 Two perspectives, Inside-Out and Outside-In that affect the business model.

Strategic aspects of industrialised house-building

Shaping tailored offers and production systems for industrialised house-building requires thorough knowledge about the target customers and clients (Hedgren and Stehn, 2014). Knowledge about the customers' financial strengths along with priorities and requirements in terms of living space and housing area are crucial for developing a limited concept that can deliver desired buildings within the identified market segment (Jansson *et al*., 2014). From an overall business perspective, industrialised house-building implies investments in pre-defined technical solutions (product platforms) and a clear selection of a niche market, a view reinforced by industry experts, presented by Johnsson (2012). There is a radical difference between business models of an industrialised house-building company offering buildings within a specified concept and a contractor, building what clients uniquely specify (Björnfot and Stehn, 2007, Pan and Goodier, 2012). By offering a defined product-concept the company has made strategic choices to focus on a specific product range and target audience. This also means that the company has made trade-offs in terms of ignoring parts of the market in favour of focusing on the defined business model, which Porter (1996) describes as an important aspect of strategy formulation.

Pan *et al.* (2012) and Vernikos *et al.* (2013) argue that a strategy for off-site production must be integrated with the entire business strategy of the company, from land acquisition through the whole process. Brege *et al*. (2014) share this view and emphasise the importance of integration and fit between the elements included in the business model concept, in order to establish a viable business model. In the cited study, Brege *et al*. (2014) use prefabrication as the starting point for describing the business models of a number of production-oriented house-building companies. Article III explored five Swedish and five North American companies and showed how the various starting points (in product or production) and the companies' respective strategic perspectives affected their business models.

The choice of production methods is of strategic importance for these companies, affecting the supply chain and the offering, following an Inside-Out approach as illustrated in Figure 12 (De Wit and Meyer, 2010). The choice of production methods (production strategy) also relates closely to the set-up of the product platform (Jansson *et al*., 2014) in terms of related trade-offs, including level of customer involvement, customization flexibility and investments in product development (product strategy) (Hvam *et al*., 2008). Having product-orientation as the starting point for industrialised house-building business model formulation increases the importance of customer knowledge as input for product development, and ultimately production methods and supply chain integration (Porter, 1996), following an Outside-In perspective (De Wit and Meyer, 2010). The strategic choices concerning product and production are important, since they set the boundaries for the company's business, determine its role in the value chain, and affect the kind of products that can be offered to customers. Johnsson (2013) provides indications that industrialised house-building companies with production strategies that are integrated with the supply chain and aimed at a certain market segment benefit the most from their platform concept.

Business model evolution

Business models are not static constructs that are set once and for all, instead they rather have to evolve and change over time, in order to adapt to the changing market surroundings (Teece, 2010). A business model description, in contrast, is a snapshot of a company's business model at a certain time, while the business model itself is under constant pressure to change (Linder and Cantrell, 2000). The ways business models change and mature over time have been scarcely addressed (Zott and Amit, 2008), despite their potential importance. However, Demil and Lecocq (2010) investigated business model evolution, which they describe as a fine-tuning process, involving both voluntary and emergent changes.

These changes occur both within and between the components of the business model and the challenge for a company is to anticipate and react to the changes, in order to sustain performance and competitiveness. Höök *et al*. (2015) very recently presented a longitudinal study of the management of a portfolio of industrialised house-building business models, describing how they have changed over time. The authors discovered distinct phases in the management of business models that were not always intended by the company. A combination of standardised production and a variety of customisation levels in different building projects proved to be difficult to manage within a single holistic production strategy. This approach led to an unintended development of new business models and illustrates the importance of continuously evaluating, fine-tuning and integrating the business model with the company's strategy. Linder and Cantrell (2000) also touch upon this subject and present a model that describes various changes of business models as responses to external pressure. The changes mentioned affect all parts of the business model, for example: offering, operational aspects, distribution channels, marketing and pricing, and market penetration. Hedman and Kalling (2003) contributed to the field of business models by presenting a framework for describing business models and including a longitudinal dimension covering the dynamics of the business model over time.

Results and analysis

This section presents results from the appended research articles, along with analyses of the results. The section is structured according to the research questions.

What characterises industrialised house-building?

Industrialised house-building is found to be a phenomenon that embraces a variety of aspects. A majority of the studied publications covering industrialised house-building, and related topics, only provide partial descriptions of the concept. A holistic description is needed for bringing knowledge about this topic together.

In the licentiate thesis (Lessing, 2006) industrialised house-building was described and analysed, based on literature studies, three case studies of house-building companies with various applications of industrialised house-building, and interviews with industry experts. A conclusion was that utilisation of platforms and prefabrication were common first steps in the development of industrialised house-building. However, several other aspects were found to be required in order to establish industrialised house-building as a way of structuring house-building, as an alternative to the traditional project-oriented building process.

This resulted in a conceptual framework describing industrialised house-building as being composed of a set of eight interdependent constructs, reinforced by a ninth construct: continuous improvements (Figure 6). These nine constructs are described more in detail in Table 3.

Table 3 Nine constituent constructs of the industrialised house-building conceptual framework presented in Lessing (2006).

	Construct	Description
1	Planning and control of processes	• Design, manufacture, assembly, site work and related processes follow a defined structure • Processes are documented and communicated throughout the organization • Thorough planning and preparation of all activities involved • Staff trained for high performance in their tasks • Roles in processes and projects are well defined
2	Developed technical systems	• Technical solutions are collected, developed and structured in systems • Standardized technology is used in the systems • Solutions are continuously tested and adjusted • Technical systems include structural frame, installations, façade, roof systems etc. • Technical systems are used for configuring complete buildings
3	Off-site manufacture of building parts	• Building parts are manufactured in facilities suitable for effective production • Suitable production equipment is used • Specialized production offers optimized and stable processes • A high degree of prefabrication means less work at the building site • Supply of material is handled with suitable equipment • Production can be executed without interference of other trades
4	Long-term relations between participants	• Participants in the processes are engaged on a long-term basis • Relations grow and develop over time • Joint development enabled through long-term relations • Individual knowledge remains in the group of participants over longer time • Selection of team members can be based on certain criteria, in order to optimize the team
5	Logistics integrated in the building process	• The flow of materials and related information is integrated with design, planning, manufacture and site work • Transports are coordinated throughout the supply chain • Material-, component- and element suppliers are involved in development processes • Suitable equipment for materials handling is used throughout the supply chain
6	Customer focus	• A focus on the customer is needed to ensure that the right products, with right quality at the right cost are produced for the end-customer and clients • Thorough knowledge about the customers' needs, priorities, expectations • Thorough investigations provide knowledge about customers • Customers and markets are divided into different segments, with specific peculiarities • Customer focus is integrated in design and development of technical systems and configuration of buildings
7	Use of information and communication technology	• Industrialised processes require accurate and reliable information • ICT provides tools that effectively handle, update and change digital material • ICT supports processes with accurate information • Digital information can be used in manufacturing equipment • Multi-dimensional digital models can be used in design, planning, analysis, manufacture, assembly, site work etc. • ICT tools support the structuring of data in technical systems, modularization and configuration • ICT tools structure and store customer and market information • ICT tools can be used for information management of performance measurements, follow-ups, knowledge sharing etc.
8	Systematic performance measurement and re-use of experience	• Performance measurements indicate strengths, weaknesses and areas of improvements • Performance measurements and follow-ups give information about the processes' efficiency • Systematic re-use of experience ensure that best practice is used in the processes • Improvements of technology, methods and processes require information about actual conditions • Collected information is used as input to improvements throughout the processes
9	Continuous improvements	• Continuous improvements are executed in all sub-areas to achieve continuously develop the production system • Improvements are made based on experience and knowledge about technology and processes • Improvements establish new levels of standards

Article I explored the development and conceptual orientation of industrialised house-building on the basis of on an extensive literature review and a continued case study covering the same three companies as were presented in the licentiate thesis Lessing (2006). This enabled exploration and analysis of the companies' development during 9 years. The literature review identified the scientific attention of publications related to industrialised house-building, summarized in Table 4. The case study provided a broad description of the companies' longitudinal development and their respective applications of industrialised house-building. Comparison of findings from the literature review and case study to the description of industrialised house-building presented in the licentiate thesis (Lessing, 2006) contributed to a more comprehensive understanding of both the constituent constructs of industrialised house-building and their holistic integration in an inter-dependent structure, from both academic and industrial perspectives.

Early publications covering industrialisation of house-building, (1996–2003) focused on technical and production-related issues, discussed in a building-project perspective. This scope is notable also for the construct *Planning and control of processes*, in early publications, while later publications put more emphasis on development of technical systems together with a process focus, indicating an increased focus on continuous processes.

Table 4 Chronologically ordered publications covering industrialised house-building and their focal orientations.

Historical review	Benefits and expectations	Organization	Business strategy and -models	Production strategy	Continuous improvements	Systematic performance measurement and re-use of experience	Use of information and Communication technology	Customer focus	Logistics integrated in the building process	Long-term relations with participants	Prefabrication and Off-site production	Developed technical systems	Planning and control of processes	
				×				×	×		×		×	Gann (1996)
							×			×			×	Crowley (1998)
								×	×	×	×	×	×	Barlow (1999)
											×	×		Gibb (2001)
									×	×		×	×	Roy et al (2003)
	×										×			Gibb & Isack (2003)
								×	×	×			×	Naim & Barlow (2003)
								×	×		×	×	×	Barlow, Childerhouse et al (2003)
								×						Barlow & Ozaki (2003)
				×				×					×	Winch (2003)
	×					×					×		×	Blismas et al (2006)
				×				×		×	×	×		Höök (2006)
				×	×	×	×	×	×	×	×	×	×	Lessing (2006)
												×	×	Sohlenius (2006)
		×		×										Unger (2006)
								×		×		×		Björnfot & Stehn (2007)
											×		×	Goodier & Gibb (2007)
							×					×		Johnsson, Malmgren, Persson (2007)
		×						×					×	Gerth (2008)
													×	Höök & Stehn (2008)
												×	×	Jansson, Söderholm, Johnsson (2008)
							×	×				×		Jensen et al (2009)
	×			×							×		×	Pan, Gibb, Dainty (2008)
							×						×	Persson, Malmgren, Johnsson (2009)
			×	×	×	×						×	×	Söderholm (2010)
									×	×			×	Bildsten, Björnfot, Sandberg (2011)
			×	×								×		Johnsson (2011)
							×	×				×	×	Malmgren, Jensen, Olofsson (2011)
			×					×			×	×		Nadim & Goulding (2011)
									×	×		×		Erikshammar (2011)
			×	×							×		×	Pan, Gibb, Dainty (2012)
			×								×			Pan, Gibb, Dainty (2012)
		×						×						Gerth (2013)
			×				×		×		×	×	×	Goulding & Arif (2013)
		×		×								×		Johnsson (2013)
	×		×								×			Vernikos et al (2013)
			×								×	×		Brege, Stehn, Nord (2014)
		×	×							×	×	×	×	Goulding et al., (2014)
		×						×						Hedgren & Stehn (2014)
				×								×	×	Jansson, Johnsson, Engström (2014)
				×										Johnsson & Rudberg (2014)
					×									Meiling, Sandberg, Johnsson (2014)
							×					×		Wikberg, Ekholm, Olofsson (2014)
×							×				×	×		Ågren & Wing (2014)

Prefabrication, historically closely associated with industrialisation, received much attention in early publications, but less in later publications. Swedish publications pay little attention to this topic, focusing on other aspects of industrialisation. However*, Prefabrication and Off-site production* are covered by most British and other international authors, stressing a difference in scope and perception of the field's starting point, as also indicated by the difference in terminology between off-site construction and industrialised house-building.

The construct *Developed technical systems* is covered by most of the Swedish publications, often in combination with some of the constructs of strategic nature (Production strategy, Business models and strategy, and Organisation), indicating that system development needs to be integrated with strategic considerations. Later publications focusing on prefabrication follow the same pattern of including strategic constructs, thereby placing the construct in a strategic perspective beyond the building project level.

Most publications focusing on *Use of ICT* also address *Development of technical systems*, indicating the importance of their integration. Few publications solely focus on continuous improvements, but nevertheless it is frequently mentioned as an important, over-arching aspect of industrialised house-building.

Customer focus gains a lot of attention, but the meaning of the term and associated concepts vary. In the early publications, customer focus and customisation are discussed from a building project perspective, while later publications stress the importance of acquiring knowledge about customers in order to design and structure building systems, product-offers and whole production systems. This trend is similar to the increasing tendency, mentioned above, towards viewing many constructs from a strategic perspective.

The construct *Logistics integrated in the building process* receives more attention in the early publications (linked to the strong emphasis on prefabrication and its relation to flows of materials throughout the supply chain) than in later publications. Logistic issues are also closely linked to *Planning and control of processes*, thus several publications focus jointly on these constructs.

Business strategy and business models for industrialised house-building are not mentioned in the early publications, but receive attention in publications after 2010. *Production strategy* is mentioned in early publications, but is addressed with increasing intensity, both as theoretical explorations and empirical validations of industrial attention after 2006. The lack of attention to strategic issues in early publications reinforces the perception that industrialisation was understood as being handled on a building project-level, merely as a technological and process-related issue. This approach is also notable in some later publications focusing on aspects of prefabrication and process planning. Organisational aspects of

industrialised house-building are not addressed before 2006, but are discussed in later publications, corroborating the increased focus on strategically oriented aspects on industrialised house-building.

A case study illustrating the emergence of industrialised house-building

The case study of three companies applying industrialised house-building with various scopes was conducted in two stages. The first part was reported in the licentiate thesis (Lessing, 2006), and the second nine years later. This provided unique research material, portraying the companies' development through different applications and industrialisation initiatives over nearly a decade.

The companies examined in the case study have explored various industrialisation applications over the years, as thoroughly described in Article I, ranging from sporadic, building-project level initiatives through factory production of volume elements using standardised technology to advanced automated manufacture by integrated production systems. Product-oriented house-building aimed at specific customer segments and companies' utilization of generic platforms and structured processes were also identified in the case study.

Product-oriented house-building companies have specialised production systems structured to facilitate efficient delivery of niche-offerings. A characteristic feature of such companies is that their product-offerings are defined end-products, in terms of complete residential buildings and apartments, designed and developed based on customer requirements. A narrow range of offerings such as this is essential for a production system utilising product platforms along with production methods and standardised processes that are strategically developed in order to balance the critical constructs. Companies offering defined end-products adopt a new role, different from that of a contractor, in terms of controlling both products and their production.

The case study further describes the three companies' development from having relatively loosely coupled sub-systems, solutions, and processes to their establishment of completely integrated production systems with structured processes and developed platforms reinforced with continuous improvements. Two of the companies established completely new, advanced production systems, and one transformed its existing processes, systems, relations and customer focus into an integrated production system. Such integrated production systems are characterised by extensively developed technical systems, processes and relations that are continuously utilised and hence constitute a backbone for the company. The case study showed that the companies developed in terms of each of the

constructs defined in Lessing (2006), and further increased their integration. Integration of the constructs is exemplified by the structuring of technical solutions in platforms supported by IT-systems that also support production and supply chain processes. Further, continuous improvements of processes and technical solutions are sparked by systematised re-use of experience, which affects the whole production system and increases its integration. These examples show the importance of developing a production system in which each construct contributes to the holistic structure, based on continuity and integration.

The companies' development and integration efforts have been based on strategic decisions made by the companies' executive management. These decisions affect the companies' offerings, production methods and processes, role and relations to customers and suppliers, as well as their organisational structures. This was also found in the literature review which revealed that many publications stressed the importance of such decisions, manifested by strong attention to the complementary constructs *Production strategy*, *Business strategy and business models*, and *Organisation*.

Throughout the period covered by the case study, all three companies restructured and integrated their organisations to improve support for continuous processes related to technical development, process development, logistics, production, information management, and market aspects. A summary of the companies' developments related to each of the characteristic constructs identified in the literature matrix (see Table 4), is presented in Article I, Table 3.

Characteristics of industrialised house-building

Both the literature review and case study reported in Article I support the assertion that the characteristic constructs initially presented in Lessing (2006), can collectively describe industrialised house-building. This conceptual framework manifests a holistic approach, including nine constructs that are required for systematic establishment and maintenance of a production system (and supply chain) that can be continuously utilised by a company or collaborative network of companies. However, the literature review also showed that several publications focus on other themes that should be included in theoretical considerations of industrialised house-building. These include *Production strategy*, *Business strategy and business models*, and *Organisation*. These are all constructs that have received increasing attention in both literature covering industrialised house-building and within the three case companies.

The construct *Production strategy* embraces strategic aspects related to choice of production methods and how they affect the rest of the company. This construct

has many links to the initial framework (Lessing, 2006), but further highlights the importance of establishing an integrated production system tailored to meet the needs of the company, its customers, and its specific offerings, and stressing the strategic impact of these aspects. The construct *Business strategy and business models* embraces company-level strategic aspects concerning business considerations related to markets, competitive advantages, customer segments, customization, financial aspects and revenue streams. This construct also has many links to the initial framework (Lessing, 2006), but stronger links to the strategic perspective and these issues' impact on the company's market role, offerings and structure. The construct *Organisation* highlights industrialised house-building's requirement for suitable organisational structures that support the process structure of the company and throughout its production system. This is also a construct of strategic nature since organisational issues affect the company and its ability to realise strategies and goals.

In Article III the scope was deepened by increasing attention to integration of production systems and utilisation of product platforms, through an extensive case study covering 10 companies: five Swedish and five North American building companies with various approaches to industrialised house-building. In the article three clusters of industrialised house-building companies were identified:

1. Product-oriented house-building companies.
2. Production-oriented house-building companies with high product predefinition.
3. Production-oriented house-building companies with low product predefinition (retained project-orientation).

This has similarities to the identification of two main strategic orientations in Article I, describing how industrialised house-building companies either are striving to increase internal efficiency or use industrialisation as a means to establish new niched offers. Among the three clusters listed above, cluster 1 and cluster 2 are two variants of the *New niched offers* orientation, while cluster 3 represents companies with *Increased internal efficiency* orientation. These strategic orientations illustrate the diversity of possible approaches for house-building companies to embrace industrialisation.

What characterises the strategic orientations of industrialised house-building companies?

Different strategic orientations

The literature review together with the longitudinal case study, presented in Article I, clarified the need to increase knowledge about strategic orientations of industrialised house-building companies. Strategic considerations are crucial for the establishment of such companies due to their need for specialisation in market segments, product platforms, production methods and integrated supply chains. In Article I, two main strategic orientations applied by Swedish industrialised house-building companies were identified and discussed. The strategic orientation above called *Increased internal efficiency-orientation*, refers to implementation of technical and process innovations, with the aim to increase the company's internal efficiency, through cost reductions and increases in both quality and reliability of deliveries. This strategic orientation is exemplified in the studied companies that developed generic technical platforms and complementary processes and IT-systems to enhance their traditional, project-oriented operations. In literature this type of strategic orientation is widely reported (cf. Gibb, 2001, Pan *et al.*, 2012, Brege *et al.*, 2014).

The identified strategic orientation above called the *New niched offers* orientation refers to industrialised house-building companies establishing new offers by enhancing their external efficiency (effectiveness), by implemented integrated production systems including use of product platforms tailored for selected customer or market niches. This approach is also described in literature (cf. Jansson *et al.*, 2014, Johnsson, 2011, Jonsson and Rudberg, 2014). Examples of this strategic orientation are presented in Article I, as four distinct house-building concepts, developed and offered by the three companies. Companies adopting a strategic orientation towards establishing new niched offers must target narrower or more clearly defined (niche) market positions than the traditional overarching position of a construction company. Thus, there is a clear need to increase theoretical understanding of such companies' strategic orientations.

In Article II the *New niched offers* orientation was explored further, focusing on product-oriented house-building companies through a case study including two Swedish companies, which were selected because they developed new offerings that they established in the market. Both were new companies that took a series of strategic decisions during their establishment, following similar routes via three phases in the development of ultimately similar business models.

- First the market place was analysed, target customer segments were identified, and specific customer needs and priorities were assessed.
- Second, offerings were developed and structured into product platforms with the identified customer requirements as input to product development. Production was initially executed by external actors, avoiding the need for heavy investment while the business matured.
- Third, production and supply chain control was increased by the companies through the incorporation of production facilities within them, thereby reinforcing the business models.

This route to developing business concepts clearly follows the market-based approach presented by Porter (1996), and described as deriving from an Outside-In perspective (De Wit and Meyer, 2010), see

Figure 12. This strategic perspective gave the companies opportunities to start their business by first identifying a market niche and target customers, then developing offerings accordingly and finally establishing tailored production systems to deliver the developed offerings to the targeted market segments.

A schematic diagram (Figure 13) was introduced in Article II to illustrate companies' orientations in terms of strategic perspectives (along an Inside-Out to Outside-In axis) and market cover (from broad offerings to niched product offers). The Inside-Out perspective corresponds to a resource-based approach (Teece *et al.*, 1997) with a starting point in the company's operational capabilities, as described by De Wit and Meyer (2010), see Figure 12. Variations in market cover of offerings are described and exemplified in the article.

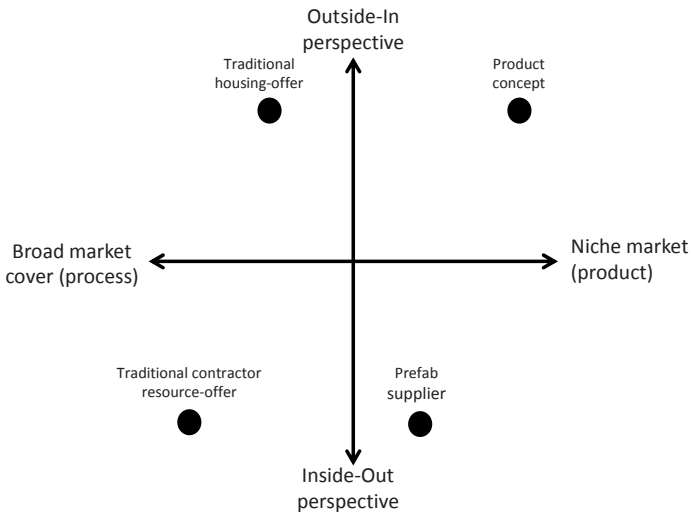


Figure 13 Schematic diagram displaying house-building companies' orientations in terms of strategic perspectives and market cover.

The two companies presented in Article II are examples of product-oriented house-building companies with offerings aimed at certain target customers representing niches in the housing market. This category of companies shows similarities with Japanese industrialised house-building companies described, for instance, by Gann (1996) and Barlow *et al.* (2003). These companies offer defined house types aimed at target customers, and have developed closed and controlled production systems, based on continuous use of standardised and highly integrated technology, processes and relations.

Another major strategic decision that both companies had to make was to choose a suitable level of product predefinition. This strongly influences a company's offering in terms of customization possibilities, the optimal production system and its setup, and the company's role in the building process and supply chain. This is discussed further in the next section of this thesis, covering characteristics of business models for industrialised house-building companies.

Article III reports a multiple case study including 10 industrialised building companies with different product and platform strategies, reflecting different strategic perspectives. One of the aims of the article was to explore these companies' strategic orientations further and thus increase knowledge and theoretical understanding about such companies. The companies are presented with brief descriptions of how they were developed, followed by descriptions of their offerings, market positions and operational platforms. The companies were analysed and categorised as deriving from an Outside-In or an Inside-Out

perspective. Four of 10 studied companies were identified as deriving from an Outside-In perspective.

Characteristics for Outside-In companies

Characteristics of these companies include a strong customer focus and development of offerings tailored to meet specific customer segments' requirements and needs. Companies working according to a Select Product variant (SV) strategy (see Figure 9) offer defined end-products (building types) with limited customization options. Such narrow offerings entail risks in terms of developing products that may not be appreciated by the market, as discussed by Zott and Amit (2008), highlighting the importance of a good fit between a company's product market strategy and business model. Three of the companies have addressed that risk by obtaining deep knowledge about their customers' needs, priorities and financial requirements. One company's involvement of home design experts and another company hiring experts on pedagogic and studying classroom utilization in order to use this knowledge in the product development, are examples of how this risk can be balanced. Such investment in product development, together with design and optimization of the end-products (building types), based on deep knowledge about the specific customer segment results in the products having carefully designed content and high customer values. This strategic route shares many similarities with the market-based approach advocated by Porter (1996).

All four Outside-In companies are relatively young companies, with no prior history in the construction industry. In that respect they have further similarities to some Japanese house-building companies that have branched out from other industries, such as the automotive and process industries, as described for example by Gann (1996) and Barlow *et al*. (2003). Three of the four Outside-In companies are SV-companies offering defined end-products. This indicates that it is crucial to apply an Outside-In perspective in order to develop a viable end-product offer. The empirical data presented in Article III indicate that companies that do not derive from the traditional construction or house-building industry have a greater propensity to embrace this strategic orientation.

Characteristics of Inside-Out companies

The Inside-Out perspective is centred around companies' competences and resources that are strategically structured to establish competitive offerings, as described by (Teece *et al.*, 1997). In the context of industrialised house-building this is a common way to describe companies' strategic orientation. As described in Article I, resource-related aspects such as prefabrication, planning, logistics and platform configuration receive much attention in literature. The dominating view of industrialised building companies is also described in terms of utilisation of various resources that are structured and integrated in order to achieve more efficient, reliable and qualitative building project deliveries (cf. Gibb, 2001), (Blismas *et al.*, 2005, Pan *et al.*, 2008).

The findings presented in Articles I and III indicate that companies deriving from roles as contractors or manufacturers of building elements, are inclined to develop strategically towards a production-oriented approach. As discussed in Article I, the three studied companies are examples of production-oriented house-building companies that have developed various industrialised house-building applications aimed at creating new improved competitive advantages through constructs including advanced manufacturing, standardised technical solutions, integrated processes, utilisation of IT-systems and supply chain collaboration.

The case study presented in Article III includes six other companies that are identified as deriving from an Inside-Out perspective. These companies apply various platform strategies (CtO, MtO and EtO; Figure 9) (Hvam *et al.*, 2008), and none of the companies have any end-product offerings (SV). A characteristic of these platform-based companies is that their core competencies are within production methods and technical development, which have been important prerequisites for their development of industrialized building concepts. The CtO- and MtO-companies have developed platforms and technical systems integrated with advanced prefabrication production methods. The two companies that apply a CtO-strategy offer turnkey solutions for building multi-family residential buildings and their platforms are designed to allow flexibility in the configuration of the buildings, but with defined limitations.

The main characteristics of inside-out companies are their utilisation of prefabrication production methods along with a product platform, but with varying degrees of development. A further characteristic is that the companies have integrated and structured their respective production systems in order to achieve effective and predictable processes throughout the building process and supply chain.

Discussion on strategic orientations

In Article I two main strategic orientations of industrialised house-building were identified, based on literature and case studies. In Article II, the *New niched offers* orientation was explored further, with a certain focus on product-oriented house-building companies. In Article III industrialised building companies were stated to derive from either a market-based, Outside-In perspective, or from a resource-based, Inside-Out perspective. When these perspectives are complemented with a scale of potential market cover and product-predefinition levels, a more diversified view of the strategic orientations emerges. A higher-resolution form of the diagram presented in Article II (Figure 13) was introduced in Article III to illustrate and clarify more specifically the relation between strategic perspectives and market cover of industrialised building companies. In this diagram (Figure 14) the horizontal axis shows levels of product predefinition (Hvam *et al.*, 2008), complementing the scale from broad market cover to niched product-offer. A low level of product-predefinition is associated with high flexibility and hence potential to target a broad market, while a high level of product predefinition means that the product platform is aimed at a more narrow part of the market.

The four Outside-In companies can be clustered together as market-driven, product-oriented building companies, illustrated as Cluster I in Figure 14.

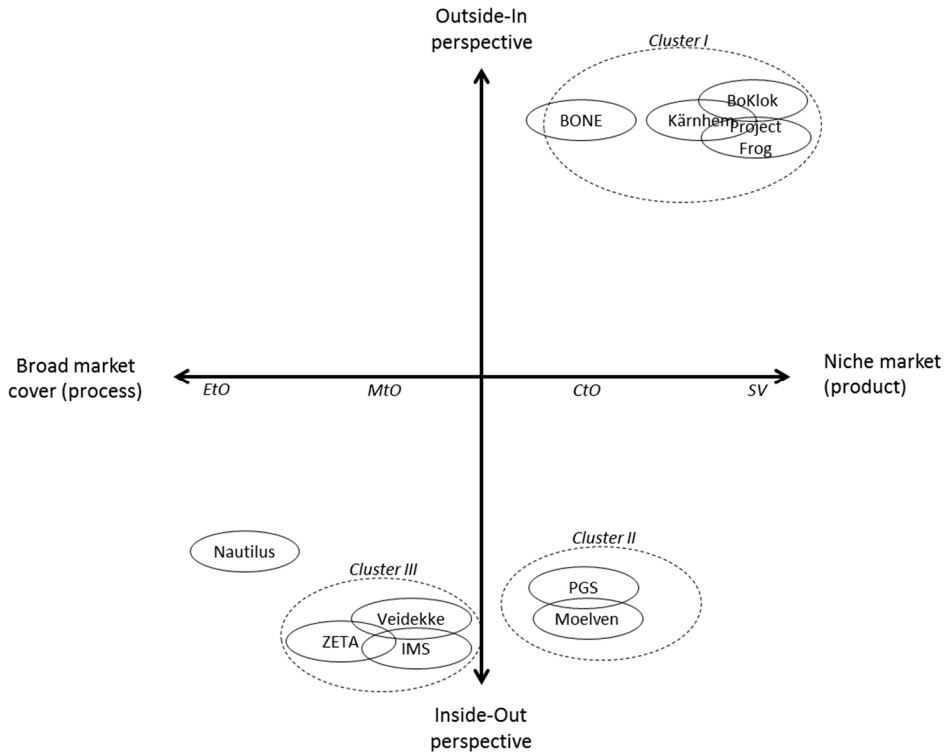


Figure 14 Strategic orientation and product predefinition level of the 10 industrialised building companies considered in Article III.

Cluster II includes Inside-Out, production-oriented companies with high levels of product-predefinition, while cluster III includes Inside-Out, production-oriented companies with relatively low levels of product-predefinition.

Clusters I and II can be seen as two variants of the *New niched offers* strategic orientation presented in Article I, while cluster III shares similarities with the *Increased internal efficiency* strategic orientation presented in Article I, along with production-oriented companies applying an EtO-strategy. These companies can be seen as hybrids that have adopted some core principles of industrialisation, while maintaining a relatively strong project-orientation, giving them advantages in their project deliveries. Clusters I and II on the other hand represent companies with more narrow and controlled offerings, facilitated by integrated production systems.

What characterises the business models of industrialised house-building companies?

Business models are suitable constructs for describing and analysing companies, including customer characteristics, what the customers value, how value is delivered, how resources are exploited and how profit is made, as described by Magretta (2002). Thus, business models are suitable for explaining how industrialised building companies operate, what they offer and their roles in both the building process and value chain. By describing the characteristics of industrialised building companies' business models, the understanding about these emerging companies is brought further.

Hence, in both Articles II and III the business model framework presented by Brege *et al*. (2014) was used for describing the studied companies holistically. The cornerstones — Market position, Offering, and Operational platform and its internal and external relations (see Figure 11) — are fundamental conceptual elements to consider when addressing industrialised building companies' business models.

The results prsented in Articles II and III showed that the strategic perspectives (and hence starting points of the business models) of industrialised building companies strongly affect the initial business model configuration and how the company is further structured, organised and developed. This emphasises that the company's origin has a large impact on its market position, what it offers and how operational activities are carried out. The case studies presented in Articles II and III stress that companies deriving from a production-orientation develop their business models with this as the starting point, while product-oriented companies use market and customer knowledge as the starting points for their business model configuration.

The conceptual framework of industrialised house-building characteristics presented in the licentiate thesis (Lessing, 2006) described how such companies operate, and emphasised the importance of customer focus and long-term relations throughout the value chain. This framework shares similarities with business model frameworks such as that developed by Brege *et al*. (2014), which is also focused on industrialised building, and other more general frameworks (see, for example, Osterwalder *et al.* (2005) Hedman and Kalling (2003) that include many overlapping elements. However, a major difference between Lessing's (2006) framework and business model frameworks *per se*, is that the latter focus strongly on the offering, describing the value proposition of the firm and its relations to the customer.

Article I noted that attention to business models and strategic aspects of industrialised house-building was increasing in scientific literature. The importance of strategic aspects, including developed business models and organisations, was confirmed by company representatives' statements recorded in the accompanying case study. Article I also emphasised the importance for industrialised house-building companies to establish integrated production systems, specialised and aimed at certain niches. Such fit between constructs within a production system is crucial in business model development, as further described in Articles II and III. As discussed throughout this thesis, there is a demarcation between project-oriented business models (the traditional models for constructing one-of-a-kind buildings, mainly involving on-site methods and uniquely designed solutions) and industrialised house-building based on product platforms and continuous processes. In the diagram presented in the previous section (Figure 14), the three identified clusters describe strategic orientations of industrialised building companies. The business models related to these strategic orientations are further discussed below.

Business models for product-oriented house-building companies

In Article II business models for product-oriented house-building companies are presented and analysed. A key characteristic of product-oriented business models noted is that the fundamental foundation or starting point is the end-product offering, based on a product platform. The two companies presented in the article followed a three-stage strategic route reflecting the development of their business models for product-oriented house-building. The three steps are related to the three cornerstones of business models; Offering, Market position, and Operational platform:

- Establishment of a good fit between the market segment (or segments) and the product offering(s).
- Definition of the company's role in the building process.
- Definition of the operational platform's structure, including prefabrication strategies and level of control and integration of the supply chain.

Establishing the fit between market segment requirements and product offerings involves strategically important decisions regarding choices of product predefinition levels and customization options, utilising the strengths of product-orientation, i.e. deep customer knowledge obtained through investigations, follow-up studies and thorough product development. These activities and investments also affect the role the company adopts in the building process. Product-orientation provides opportunities to act as a product-offering company, in sharp

contrast to a contractor's role. In order to establish well-defined product-offers, the company needs product development capabilities and an organization that can manage such activities and sustain related knowledge. Thus, the operational platform needs to be structured according to the product-offering and the market position.

The case study presented in Article II illustrates how the two product-oriented house-building companies successively developed their business models. After identifying a demand for low to intermediate cost housing and identifying the target customers, the companies tailored their respective product-offers. Both companies established themselves in the building process by taking on twin roles as housing developers and manufacturers. This enabled them to control not only the products but also their production and supply chain. Further, both case companies established processes for managing product development and production competitively. This fit between their operational platforms and offerings enabled the companies to keep costs down, allowing them to achieve target prices and profit margins consistent with their strategies and value propositions.

In Article III, four of the 10 companies considered were identified as deriving from an Outside-In perspective, see Figure 14. In addition, the North American companies were found to share many similarities, although some apply CtO and others apply SV strategies.The main differences between these strategies are related to the flexibility in their offerings. CtO-companies use their product platform to derive a variety of buildings, but based on standardized solutions, while SV-companies offer defined end-products as described by Meyer and Lehnerd (1997) and Hvam *et al.* (2008).

All four Outside-In companies developed their business models with thorough customer knowledge as the starting point and structured their operational platforms accordingly. They all focused on developing product platforms. However, the Swedish and North American companies apply different production strategies. After testing their business models, the Swedish companies established their own manufacturing facilities while the North American companies out-sourced production to external suppliers and contractors. These companies put efforts into training and supporting their partners, in order to achieve high end-product control. The four Outside-In companies are summarized in Table 5.

Table 5 Summary of business models of four companies deriving from an Outside-In perspective.

	Outside-In perspective			
	BoKlok	BONE Structure	Kärnhem	Project Frog
Offering	Defined building types and apartments, built and offered in complete housing areas.	Frame-and-shell product platform for single family houses. Architectural & engineering service.	Defined house-models are built and offered in complete housing areas.	Design of pre-defined, complete education buildings. Supply of complete kit of parts for these buildings.
Market position	Project developer and design+build contractor. Aim at defined low-cost segment. No customization.	System supplier. Aimed at defined high-end customer segment. Very high customization.	Project developer and system supplier. Aimed at defined medium-cost segment. Limited customization within defined range.	System supplier. Aimed at defined medium-cost customer segment. Limited, customization within defined range.
Operational platform	In-house product development and production of highly finished volume elements in own factory. Assembly and site-work by own staff.	In-house product development and engineering, Outsourced component production. Assembly and site work by certified contractors.	In-house product development and element production in own factory. Design, assembly and site work executed by partners.	In-house product development and engineering, Outsourced component production. Assembly and site work by certified contractors.

The case study presented in Article II revealed that establishment of the companies' respective business models required relatively low investments, in contrast to other industrialisation initiatives such as some of the concepts presented in Article I. Due to product-oriented house-building companies' starting point in product-orientation, the initial costs were kept low and mainly aimed at product development. As production was executed by external manufacturers and contractors it did not require investments. When the companies' product offers had been launched and several building projects were built and appreciated by the customers, the companies decided to increase their control of the production system. This involved investments in production facilities, but they were kept relatively low due to the specialised production of the narrow product range and hence relatively low requirements for advanced, flexible production equipment. This illustrates that a product-oriented business model can be developed in stages, with limited initial investments and that further investments in increased process control also require limited investments.

As presented in Article III, the two North American companies Project Frog and BONE Structure have followed similar approaches to those that BoKlok and

Kärnhem initially applied, avoiding high initial costs for establishing production facilities. Both the North American companies also exploit outsourcing to enable rapid expansion into new markets, without investing in factories.

These findings show that successful industrialised house-building does not necessarily require large-scale and large volumes of built units, in sharp contrast to the view of industrialised building as depending on large-scale production and heavy investments (cf. CIB, 1965, Deeson, 1967, Pan and Goodier, 2012). The studied product-oriented building companies show that tailored systems producing relatively few units per year can be established, with limited investments and high customer value. The critical factor is to establish a good fit between the offering and the market position, together with a suitable operational platform for its specialised purpose, with balanced investments.

Business models for production-oriented building companies

In Article III two clusters of production-oriented building companies (see also Figure 14) were identified and categorized as deriving from an Inside-Out perspective:

- Production-oriented building companies with high product predefinition levels.
- Production-oriented building companies with low product predefinition levels.

The business models of these two categories of companies show both similarities and differences. Common features include a resource-based starting point (Teece *et al*., 1997). In the case study presented in Article III, six Inside-Out companies' business models were presented. These are summarized in Table 6.

Table 6 Six industrialised building companies deriving from an Inside-Out perspective.

	Inside-Out perspective					
	Moelven	Nautilus	Peab PGS	Veidekke	ZETA	InterModal
Offering	Design+build offering for multi-family residential buildings. Specific product range based on defined product platform and production method.	Design and build offering of uniquelly designed and built residential buildings in urban infill locations.	Design and build offering for multi-family residential buildings. Specific product range based on defined product platform and production method.	Design and build offering for wide range of multi-family residential buildings, based on technical platform and selected production methods.	Design and build offering for wide range of multi-family residential buildings, based on defined technical platform and factory based production.	Design and build offering of education buildings, based on defined technical platform. Automated production of structural frame.
Market position	Design+build contractor. Aimed at medium cost segment. Customization within defined range.	Project developer and design+build contractor. No defined customer segment. Very high customization (project unique).	Design+build contractor. Aimed at low to medium cost segment. High customization within defined range.	Design+build contractor. Aimed at medium-cost segment. High customization.	Design+build contractor. No specific customer segment, customization within defined range.	System supplier. Aimed at low to medium-cost segment. Customization within limited range.
Operational platform	In-house design, planning and production of highly finished volume elements in own factory. Assembly and site work by own staff.	In-house design, planning and production of highly finished volume elements in own factory. Assembly and site work by own staff.	In-house design, planning and production of elements in own factory. Assembly and site work by own staff. Advanced, integrated IT system.	In-house factory for installation/ bathroom modules. Partners supply prefab building elements. Extensive use of IT. Assembly and site work by own staff.	In-house design, planning and production of highly finished volume elements in own factory. Assembly and site work by own staff. Extensive use of IT.	Outsourced design, engineering, production and site work.

Similarities of and differences between production-oriented business models

Two companies considered in Article III (Peab PGS and Moelven) are described as following a CtO-strategy (Hvam *et al*., 2008). Their offerings include designing and building residential buildings within defined ranges, for clients in the market. This is achieved through a high degree of process and product control, enabled by their integrated production systems. Two other companies (Zeta and Veidekke Max), follow a MtO-strategy (Hvam *et al*., 2008), offering high levels of customisation, also utilising extensive factory production and controlling the on-site work, supported by IT-systems and standardised processes. These four companies show many similarities in their business models' operational platforms.

However, the MtO-companies operating in a context of project delivery, offering wider ranges of products (projects) and utilising lower levels of predefinition.

The establishment of production systems entails risks in terms of investments in platform development and establishment of production facilities that need to generate returns. Different approaches to handling these risks are identified in Article III. The CtO-companies addressed this risk by establishing a good fit between market requirements and their offerings, through insights and knowledge about their customers' preferences. They also defined their platforms' limitations and features in order to enable good matches. Veidekke Max and Zeta chose to develop platforms with lower degrees of predefinition (MtO) and hence allow higher levels of flexibility and customer-specific solutions (Jensen *et al*., 2015). This provided broader market potential that leverages the risks associated with their platform investments and their constraints. However, lower levels of predefinition result in more project-specific work and eliminate some of the advantages of platform-based construction. Another way to handle risks is exemplified by IMS, which outsourced production to specialized suppliers and sub-contractors, thereby keeping investments low.

A key challenge for production-oriented, platform-based companies is to maximize the benefits from investments in platform development in terms of effective design, manufacture and building processes, while providing high-quality buildings with high customer value. This means establishing a good fit, both internally (i.e. between the offerings, the operational platform and the market position of the company) and externally, i.e. between the company and the marketplace it operates in (Brege *et al*., 2014). A major difference between the production-oriented and product-oriented companies and their business models, is related to product control. The product-oriented companies offer defined products and hence strongly control the end-products. The production-oriented companies need to manage customer interactions and match their platforms' capacities with the customers' requirements to a higher extent. This highlights the importance of having a clear business model that can guide the company through the challenges of finding the right customers and the right building projects.

Business model evolution

Business models are not static constructs, instead they mature and evolve over time in response to market demands, developments in technology and processes, and fine-tuning of their components, as described by Hedman and Kalling (2003). Business model evolution is further described by Demil and Lecocq (2010) as being initiated by either voluntary or emerging changes. The case study reported in Article I illustrates how the companies' various applications of industrialised

house-building have changed over time, resulting in redefined offerings and fine-tuned operational platforms. The case study presented in Article III shows how the considered companies have developed their business models and successively increased integration and fit between and within the business model's building blocks.

The changes reflect the companies' strategic perspectives (Inside-Out or Outside-In) and starting points. Article III empirically reveals that Outside-In companies that initially focused on product development based on customer knowledge gradually increased focus on operative issues such as production and supply chain management. This balanced focus on operational issues along with the strong market approach is indicative of voluntary changes, sparked by the companies' experience and insight about the interdependence between their business models' components. Other examples described in Article III include uses by mature CtO-companies (deriving from an Inside-Out perspective) of their platforms in numerous building projects and successive acquisition of deep knowledge not only about their platforms' performance but also about their customers' appreciations and expectations. This knowledge has been used as input for improvements and changes of design, technology and processes in order to increase customer value. These empirical examples illustrate business model evolution from production-focus to a more balanced position, integrated with increased market knowledge.

The second diagram in Article III (Figure 15) indicates the companies' fine-tuning of their business models and transition of strategic positions. The companies were not found to radically change their strategic perspectives, but to improve the balance of their business models' components reflecting the origins of the companies. The different routes chosen by the companies are elaborated in Article III.

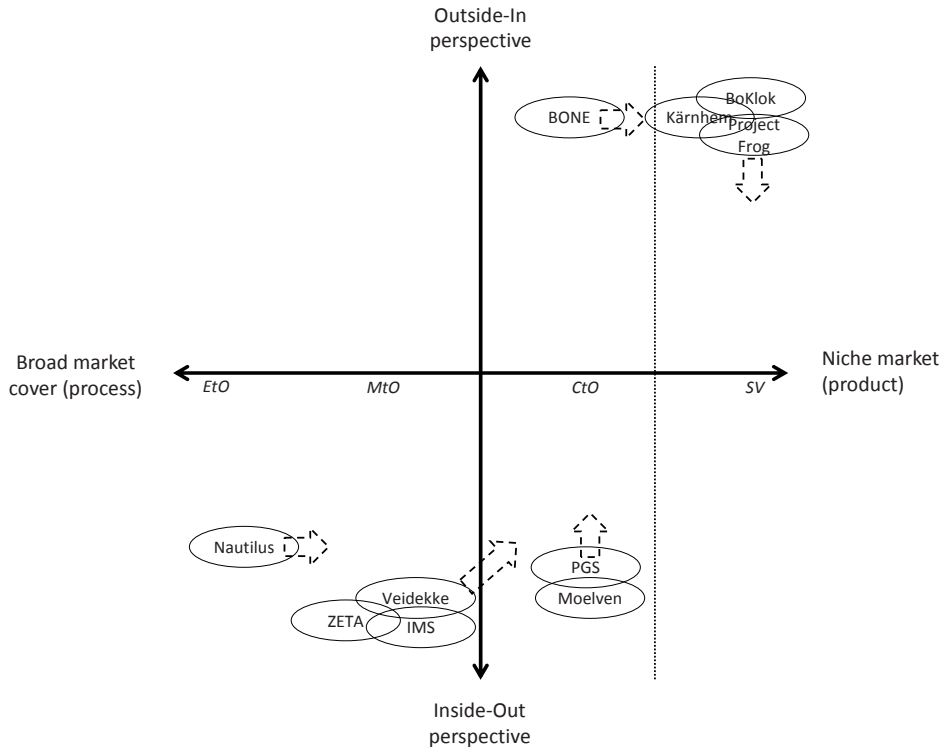


Figure 15 Identified changes in case companies' strategic positions reflecting evolution of their business models

An important limitation of business model evolution was identified for companies changing from applying a CtO-strategy towards a SV-strategy, due to the difference in offering defined end-products and producing buildings based on customer requirements utilising a product platform.

Conclusions

Characterisation of industrialised house-building

Industrialised house-building is characterized by a set of constructs that are systematically integrated in order to establish production systems, structured for a continuous production of buildings, aimed at certain market segments and product ranges. This strongly enhances the degree of continuity throughout processes, technology and relations, in comparison to project-oriented house-building.

Twelve constructs characterise industrialised house-building. The first nine constructs are: Planning and control of processes; Developed technical systems; Off-site manufacture; Long-term relations; Logistics integrated in the building process; Customer focus; Use of information and communication technology; Systematic performance measurement and re-use of experience; Continuous improvements. Three additional constructs contribute with a strategic perspective stressing that industrialised house-building need to be managed strategically on a company level: Product strategy; Business strategy and –models; and Organisation. Together these constructs provide an aggregated, holistic framework that emphasise the diversity and strategic aspects of industrialised house-building.

Industrialised house-building can be structured to either establish new niched offers on the market, or to achieve increased internal efficiency within the company. These two main strategic orientations require different strategic considerations that affect their respective business model configurations.

Strategic orientations of industrialised house-building companies

Industrialised house-building companies generally derive from either a market-based Outside-In perspective or a resource-based Inside-Out perspective. These perspectives reflect the companies' starting points and are indicative of three main strategic orientations when combined with their product pre-definition levels and potential market cover (which may range from niche to broad). The first strategic orientation is product-oriented house-building. Companies with this orientation offer a narrow range of defined products, targeting a specific customer segment and is an example of the *New niched offers-orientation*. The other two are both

production-oriented, but offering *either* customized buildings to market niches through platforms with high product predefinition and defined scope (*New niched offers*) *or* a wide range of customized buildings, based on generic platforms targeting a wide customer segment, a variant of the *Increased internal efficiency orientation.*

Business models for industrialised house-building companies

Three main categories of business models for industrialised house-building companies are identified, as described above. A characteristic feature of all these business models is the companies' strive to establish a tight fit between market segment requirements and offerings, based on product platforms enabling customization within defined limits. The structure and utilization of operational platforms differ, reflecting various approaches ranging from in-house to out-sourced production. However, a common characteristic of both product-oriented and production-oriented companies is effort to control production processes tightly to ensure high product control.

Product-oriented house-building companies' business models can be successively developed and implemented, which facilitates attempts to balance investments in production with the business model's establishment in the market. Production-oriented companies need to carefully tailor their production systems with a fit between investments in product platform development and production facilities, balanced with the requirements of the target customer segment.

Through business model evolution, product-oriented and production-oriented business models change over time. Product-oriented companies increase focus on operative issues while production-oriented companies reinforce their business models by using increased market and customer knowledge to enhance customer value.

Methodological discussion

Results, analyses and conclusions in this thesis have been inevitably affected by the methodological considerations and choices made during the research, described as the research strategy, design, and process. Two main sources have been used for contributions to theoretical understanding: literature studies and case studies. These were used for theory refinement and jointly contributed to the composition of a conceptual framework and the elaboration of strategic orientations and business model analyses. In qualitative research the researcher himself is the key instrument, affecting how data are gathered, interpreted and

analysed. My background as an industry consultant (with close relations to research and development) has inevitably affected my view of industrialised house-building and consequently this research, its results and conclusions. However, the purpose of this research was to increase understanding of industrialised house-building and its strategic development. By using case study methodology for the empirical data collection, my background reinforced both the research design and research process, in terms of enabling discussions and establishing trust between me as a researcher and the people involved, and facilitating access to detailed information. This enhanced the validity of the research, which was additionally increased through triangulation. The case studies included in the research are impossible to repeat since they were conducted over long time periods and included specific meetings between individuals. Nevertheless, the meetings, seminars, interviews and company visits are thoroughly described in an attempt to achieve high reliability. The literature studies could be repeated, but the interpretations and aggregated analyses have been affected by me as a researcher.

Industrial contribution

The empirical foundations of research presented in this thesis were obtained from case studies of companies acting in the house-building industry, which were undertaken to improve theoretical understanding of industrialised house-building on holistic and strategic levels. The findings are expected to be beneficial for industry representatives, and contributions expected to be of specific interest for these readers are discussed below.

This thesis contributes to the understanding of industrialised house-building, its various applications, key constructs and strategic issues. The conceptual framework for industrialised house-building emphasises the importance of integrating a set of constructs into production systems that are continuously improved and strategically structured and managed. This is expected to be beneficial for industry representatives in terms of extending the view of industrialised house-building from a tactical and operational project-level to a holistic, company strategy-level perspective. The company descriptions and analyses may provide valuable sources of information and inspiration for individuals and companies. This thesis, and appended research articles, presents various relevant applications, developments, information and empirical data from highly pertinent case studies, which the author hopes will be illuminating for both practitioners and academics involved in the field who take the time to read and reflect on the contents.

Further, this thesis presents and discusses strategic considerations and perspectives of industrialised house-building companies that will hopefully provide guidance for companies aiming to develop and utilise methods and principles related to industrialisation. The findings regarding the presented, analysed and discussed business models of such companies highlight the importance of establishing a good fit between the model components, particularly since several historical attempts to apply industrialised house-building failed due to a lack of balance between market, product and operational aspects.

Industrialised house-building as a driver for new business models – a discussion

Industrialised house-building companies require structures and operational platforms that include opportunities for further development of their business models. Such companies' utilisation of product platforms, innovative production methods, structured processes and systematic improvements etc., give them more similarities to manufacturing companies in other industrial sectors than to traditional project-oriented construction companies. Several lessons can be learned from studying how other industrial sectors have developed in order to enhance knowledge and insights about how industrialised house-building companies could be developed. Important aspects that have strongly influenced manufacturing companies' success are combining physical products and services, and globalisation/ internationalisation (Porter, 2008). Both of these aspects are highly relevant for the development of industrialised building companies and may signifycantly affect such companies' business models. Thus, they are discussed below.

Product-service offers for industrialised building companies

In contrast to traditional project-oriented building companies, industrialised building companies have core assets in terms of their integrated production system, including its product platform. This constitutes a fundamental requirement for product-service offerings, as described by e.g. Manzini and Vezzoli (2003) and Mont (2002).

A product-service offer from an industrialised building company would significantly affect the company's business model. The company's market position would be changed due to the new long-term relations with the customers throughout the product's life cycle. This would provide completely new revenue

streams, but also require organizational changes in order to manage and execute services. The company would have to establish new capabilities and a network of (internal or external) providers for various services. Such a dramatic change of business model would entail risks in terms of investments and warranty commitments that would have to be balanced with the new revenue streams and potential returns.

Based on the findings in Articles II and III, illustrating the various categories of industrialised building companies, the companies that are probably best placed for establishing product-service offers, are companies in Clusters I and II, applying SV or CtO strategies (Figure 14). This implies that a product-oriented PSS, as described by Tukker and Tischner (2006), would be suitable as an initial approach.

Industrialised building companies have the requirements for developing their business models to include services throughout their products' life cycles. This provides opportunities for them to diversify offerings beyond those that traditional project-oriented companies can offer, as the latter lack the essential continuously utilised, integrated production systems with product platforms.

Industrialised house-building companies operating on an international market

Building companies traditionally operate in regional markets, with resource-based contracting offers comprising their core offerings. In contrast, industrialised house-building companies are structured for repetitive, standardised processes throughout design, production and supply chain and utilise product platforms. This give such companies excellent resources, facilities and competences for expansion through increasing production volumes aimed at new markets, or duplicating and adapting their business models in additional markets, establishing new production systems and supply networks.'

In the case study presented in Article III, a distinct difference between the Swedish and North American companies was identified. The North American companies operate in a large domestic market with great potential for growth and expansion. In contrast, the Swedish companies solely operate in the small Swedish market, except one company that has expanded on small-scale to other Scandinavian countries. There are obstacles in the surrounding markets due to differences in national building codes and regulations. Nevertheless, the Swedish companies have interesting opportunities for expanding their markets, and various strategies are available for industrialised building companies aiming to expand internationally. Product-oriented, Outside-In companies have opportunities to apply their business models in new markets. In order to leverage the risks in

market expansion, establishment in a series of stages is possible by initially outsourcing production. Production-oriented Inside-Out companies have opportunities to increase production volumes in their production facilities and ship modules and components to new markets, where contractors can be hired to assemble and finish the buildings. For production-oriented companies it is crucial to establish a production system, with sufficient product and production control, in the new market.

Describing companies' expansion strategies in detail is beyond the scope of this thesis. However, a conclusion is that the structure of industrialised building companies' business models enhances opportunities for international expansion.

Further research

Industrialised house-building is presented in this thesis as a phenomenon with characteristic, tightly integrated features (described by a corresponding set of inter-related constructs) that must be strategically managed and developed. Further research in this field is proposed to include investigations of the relations between the constructs and their effects on the whole production system to strengthen and extend relevant theory, and provide practical guidance for practitioners.

Concerning business models and strategic orientations of industrialised house-building companies, it is also proposed that further research should include deeper studies of such companies' investments in product platforms and production systems, in relation to market penetration and profitability. This would increase understanding of these complex phenomena and contribute to evaluations of different business models' sustainability and robustness.

As discussed above, industrialised house-building companies have interesting resources, facilities, competences and (hence) opportunities for developing their business models by offering combinations of physical products and services. This would undoubtedly mean dramatic changes in the business models, thus this issue warrants further research, focused on new product-service-offers, operational requirements and opportunities, as well as risk- and market evaluations.

Industrialised house-building companies also have opportunities to introduce their offerings to new markets through globalisation and internationalisation, as discussed above. This is another issue that warrants further research in terms of identifying obstacles and hindrances along with evaluating the market opportunities. This is crucial for further evolution and development of industrialised house-building companies, affecting all aspects of their business models including the offering, the market position and the operational platform.

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About the author

Jerker Lessing has more than 15 years of experience as a consultant in the construction industry, involved in numerous development projects aimed at industrialised house-building. Since 2004, he has concurrently conducted research at Lund University. He is an appreciated lecturer, has co-authored a book about industrialised house-building and has been a visiting researcher and lecturer at Stanford University.

As a contrast (or rather a complement) to his professional work he spends his spare time renovating his own house, an old half-timbered house from 1836, using traditional materials and techniques. His interest also includes sailing his classic wooden sail yacht in the waters of Öresund, the strait between Sweden and Denmark, as well as spending time outdoor with his family.

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