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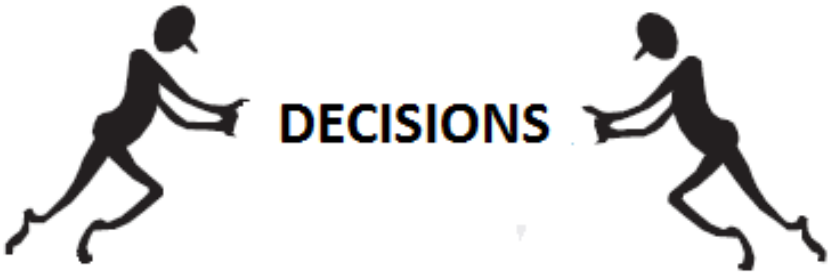

Industrialised building processes for platforms

Master of Science Thesis in the Master's Programme Structural Engineering and Building Technology

FRIDA HOLMQUIST

Department of Civil and Environmental Engineering
Division of Structural Engineering
CHALMERS UNIVERSITY OF TECHNOLOGY
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Master's Thesis 2013:146

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Cover:
Figure illustrating the productivity–flexibility trade-off, the principal of how much in a project that is decided without the customer and how much by the customer (inspired from Rudberg and Wikner, 2004)

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ABSTRACT

The building industry needs to change to meet customer requirement while keeping quality and reducing costs and time for each project. The traditional building industry is said to be more inefficient than other production industries, which might lead to higher costs and longer building time than planned. The building process is focused on the uniqueness and singularity of the projects. The purpose of this master thesis project was to find similarities in activities that can be systemised in a more streamlined building process. This was carried out by investigating activities in different value chains represented by different concepts.

In order to do this was a literature study carried out as well as a case study. The case study concerned four different multifamily dwelling concepts at NCC. The industrialisation was studied from eight different aspects. The research clarified how industrialised different concepts are at NCC and how many decisions that are carried out in the product development process and what a customer can choose in a specific project.

This research focused on the activities in the traditional building process's five stages: concept, design, planning and control, manufacturing and assembly that are carried out for each project with an emphasis on the first two, concept and design. Subsequently, this research was concentrated on a more industrialised building process. Industrialisation is seen as a measurement of how much of the process and the techniques that are repeated from project to project. Furthermore, the two design processes in the industrialised building process: product development process were decisions are made without a customer and configuration process were decisions are carried out the customer by were studied. The decisions that are decided on in the product development process should remain the same for each new project.

The results show that either very little or a lot of decisions are carried out in the product development process. Further, the more finished a concept is the harder it is to use, and the finished concepts should have as many aesthetical choices as possible to be useable. The most industrialised aspect for all the concepts is developed technical system and the least industrialised are concerning the logistics and the off-site production. The result also shows that the incentive of a concept does not have to be to be industrialised to accomplish it. Furthermore, different ways to improve industrialisation of the building process are presented.

Key words: Buildings process, industrialisation, production strategies, design process, industrialised design process.

Industriella byggnadsprocesser för plattformar

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SAMMANFATTNING

Sammanfattning

Byggnadsindustrin behöver ändras för att kunna möta kundernas behov medan kvalitén behålls och byggnadstiden och kostnaden reduceras.

Syftet med detta examensarbete var att undersöka vilka aktiviteter som är lika mellan mera traditionella byggnadsprocesser och mera industrialiserade byggnadsprocesser. Detta gjordes för att se likheter mellan aktiviter mellan olika processer och för att sedan kunna bestämma det bästa sättet att standardasera aktiviteter i plattformar.

Det traditionella byggandet är ofta sagt att vara mera ineffektivt än andra produktions industrier, vilket leder till högre kostnader och längre byggnadstider än behövt. Det fokuserar på det unika och säregna i projekten. Dessutom tog denna forskning upp aktivitet i det traditionella byggandets fem stadier: koncept, projektering, planering och kontroll, byggandet och montering som görs för alla projekt.

Denna forskning fokuserade främst på ett av svaren på ineffektivitetsproblemet i byggindustrin, ett mera industriellt byggande. Industrialisering är ett sätt att mäta hur mycket av processes som är återkommande from projekt till projekt. Dessutom så berörde denna forskning det industrialiserande byggandets två projekterings stadier: produktutvecklings processen där beslut tages utan en kund i åtanke och konfigureringsprocessen där besluten tages utav kunden.

För att kunna undersöka detta var en litterär studie och en fallstudie utförd. Fallstudien var på fyra olika koncept av flerfamiljbostäder på NCC. Industrialiseringsgraden var studerad utifrån åtta olika aspekter. Dessutom är olika sett att förbättre industrialiseringen av byggnadsprocessen presenterad. Forskningen klargjorde hur industrialiserade de olika koncepten är på NCC och hur mycket av besluten som tages i produktutvecklings processen och vad kunden sedan kan besluta i projekten. Besluten som tages i produktutvecklings processen är samma för alla projekt.

Resultatet visade att det är antingen väldigt mycket eller väldigt lite som beslutas i produktutvecklings processen. Men också att ju mera utvecklade ett koncept är desto svårare är det att hitta en kund och att de utvecklade projekt bör ha så många estetiska val som möjligt. Den mest industrialiserad aspekten för alla koncept är ett utvecklat tekniskt system och det minst industrialiserade aspekterna berör logestik och förtillverkning av byggdelar. Resultaten visade också att ett koncept inte behöver vara tänkt att vara industrialiserat för att åstadkomma det.

Nyckelord: Byggnadsprocess, industrialisera, produktionsstrategier, projekteringsprocessen, industrialiserad projekteringsprocess.

Contents

Preface

This is a master thesis in Structural Engineering and Building Technology at Chalmers University. The work has been carried out at NCC Engineering in Gothenburg.

I want to say a big thanks to Karin Gustafsson at NCC Engineering, who worked as a supervisor and sounding board during the work and who provided valuable guidance and feedback. I also want to thank my other supervisors Dan Engström at NCC Engineering. Many thanks also to the people I interviewed, who shared their time and knowledge. I would also thank my examiner Björn Engström, Chalmers, who gave advice and comments during the work time, as well as others involved in development projects that contributed knowledge on the subject. Finally, thank you to the people around me who took the time to read the work and provide feedback.

Translations of quotations are made by the author.

Gothenburg Dec 2013

Frida Holmquist

Definition of terms

Process – A chain of activities that in a recurring flow creates value for a customer (Lessing, 2006).

Project – defined with a start and an end point. (Lessing, 2006)

Flexibility – degree of uncertainty that is deliberately allowed in a system to increase value for the customer (Söderholm & Johansson, 2010).

Standardisation – the condition in which a standard has been successfully established, usually to make communication easier and gain economies of scale. (Business dictionary, 2012)

Upstream activities - are close to the raw material end of the value chain where the value adding comes from transforming the raw material into standardised products (Guam, 2012).

Downstream activities - are characterised by meeting customers' various needs (Guam, 2012).

Supply chain – Entire network of entities, directly or indirectly interlinked and interdependent in serving the same consumer. It comprises of vendors that supply raw material, producers who convert the material into products, warehouses that store, distribution centres that deliver to the retailers and retailers who bring the product to the ultimate user. Supply chains underlie value-chains because, without them, no producer has the ability to give customers what they want, when and where they want, at the price they want. Producers compete with each other only through their supply chains and no degree of improvement at the producer's end can make up for the deficiencies in a supply chain, which reduce the producer's ability to compete. (Business dictionary, 2012)

Value chain – Interlinked value-adding activities that convert inputs into outputs which, in turn, helps to create competitive advantage. A value chain typically consists of inbound distribution or logistics, manufacturing operations, outbound distribution or logistics, marketing and selling, and after-sales service. These activities are supported by purchasing or procurement, research and development, human resource development, and corporate infrastructure. (Business dictionary, 2012)

NCC Housing – the division of NCC that develops living areas and multi-family dwellings (NCC Housing Sweden, 2008-2014).

NCC Construction – the division of NCC that produces for example railways, bridges and dwelling houses (NCC Construction Sweden, 2008-2014).

NCC Engineering – NCC specialists for structural, geotechnical or installations technical and design questions. The division of NCC that make the designs in projects where NCC Housing is the client (Gustavsson, 28/05/13).

Customer order decoupling point – the point in the process that separate decisions made without a customer from decisions made by a customer (Rudberg & Wikner, 2004).

1 Introduction

This chapter provides the rationale for why research was carried out, followed by the focus and research question. It also explains the motives for methodology of the research and presents finally the outline of the report.

1.1 Background

Many European countries have realised that the building industry needs a change. This has resulted in different reports that evaluate the building industry (Kok, 2007). Examples of such reports are 'Construction Task Force' and 'Rethink Construction' in the UK and' Regieraad Bouw' and 'PSIBouw' in the Netherlands, ProjectHus in Denmark and Vision 2010 in Finland (Koskela, Ballard, & Howell, 2003; Kok, 2007). Corresponding report in Sweden is called 'Skärpning Gubbar' and was published in 2002 (Byggkommisionen, 2002). One reason for this concern is that the construction industry generally accounts for a high percentage of the economy. With an annual turnover in Sweden of around 250 billion SEK, it represents around 10% of the annual BNP (http://www.bygg.org/faktaostatistik, 2013). Therefore big savings can be achieved if changes are made.

The building industry is often criticised as being more inefficient than other production industries. This may be due to low quality and errors, which lead to higher costs and longer building time than planned. The traditional building industry is said to be demand-driven, fragmented and to have one-of-a-kind projects, a great deal of onsite production and temporary organisations (Lessing, 2006). It is not designed to be a continuous process but is focused on the uniqueness and singularity of the projects. At the same time statistics show that the price of production of housing have increased more than the Swedish consumer price index over the period of 1970 until 2011, see Figure 1.1. (Byggkommisionen, 2002)

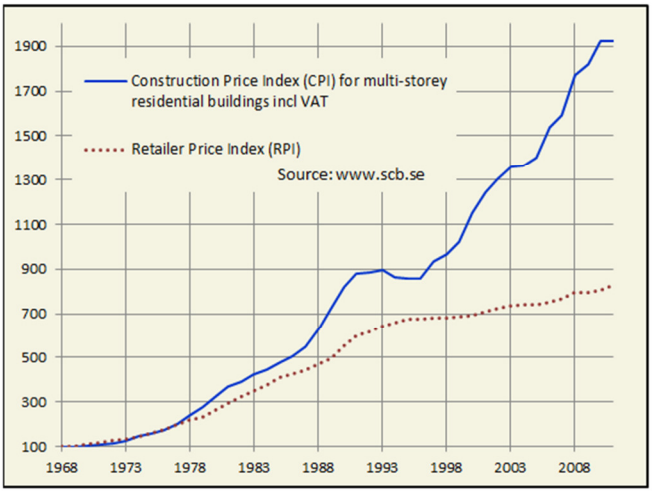

Figure 1.1. Cost for apartment buildings versus consumer price index (Statistiska Centralbyrån, 2013 and Engström, Dan 2013).

One answer to the productivity issue could be implementing a higher degree of industrialisation in the building process. A Swedish study takes up eight areas which

are included in the concept of industrialisation in the building industry (Lessing, 2006).

- Planning and control of the processes
- Developed technical systems
- Off-site manufacture of building parts
- Long-term relations between participants
- Logistics integrated in the construction process
- Customer focus
- Use of information and communication technology
- Systematic performance measurement and re-use of experience

The eight aspects of industrialisation make up the industrialisation house-building model (The IHP model) represented by the wheel seen in Figure 1.2. (Lessing, 2006)

Figure 1.2. The industrialisation House-Building Model wheel (Lessing 2006)

Industrialisation can be seen as a measurement of how much of the process and the techniques that are repeated from project to project. The housing industry is said to have a great potential for industrialisation. As industrialisation requires repetition of processes and production, this could easily be achieved when producing houses (Höök, 2008). The industrialised housing industry is growing in the market with a share of approximately 15% in 2008 (Jansson, Söderholm, & Johnsson, 2008).

There are two kinds of design processes in the industrialised building process: the product development process and the configuration process. These describe how much that is decided without a customer and how much that is unique or adapted-to-order, i.e. decided with a customer, see Figure 1.3. This can be termed according to different production strategies that show costumer order decoupling point. The strategies express how much choice the customer has at the beginning of each project and how much is standardised. (Jansson, 2010)

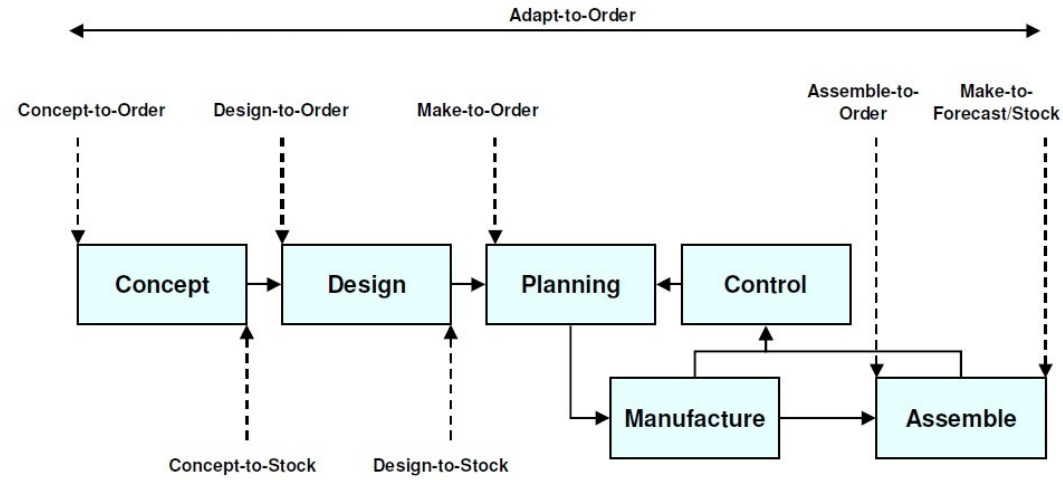

Figure 1.3. An overview of the building process together with the different production strategy. (from Kok 2007)

Many of the big construction companies in Sweden have addressed low efficiency in construction and are trying, in various ways, to improve it. One of them is NCC, which is handling a range of different value chains. NCC stated in its annual report 2012 that: (NCC.se, 2013)

"*NCC and its customers jointly identify needs-based, **cost** effective and high-quality solutions that generate added value.*"

Jansson (2010) states that efficiency and control can be achieved through defining the process and by identifying the bottlenecks and non-value adding activates. The most suited solution of the activity can then be described in a product platform for the company.

1.2 Focus and research question

What does the building industry need to change in order to accomplish a well-defined building process with a higher degree of repeatability, to produce high quality customised housing at reasonable cost (Andersson, 2012)?

As stated above, this is a question that many of the big construction companies are trying to answer. As Jansson (2010) stated, a well-defined construction process can help to find bottlenecks and non-value adding activities as well as find similarities that can be systemised in a more streamlined process. NCC has many different value chains in-house represented by different concepts and therefore wants to find activities that are similar for the different concepts and find the most suitable which can then be placed into a general product platform for the company.

To give a background and an idea of what activities most of the projects are made up of, the first research question was:

What activities make up a traditional ad hoc project?

In order to identify the similarities and differences in the design of construction projects that use different production strategies the second question was:

What activities consist more industrialised projects of today?

One part of the question above was then to identify how much of the concept is performed without a customer and how much can be alternated by the customer. Then to compare the similarities and identify what activities that can be standardised, the outcome of the research was:

What strategic choices could be made from the similarities in activities?

1.3 Demarcations

This research should only be focused on concept from NCC in Sweden, but articles and reports from other countries should be studied and referred to. This should give a broader understanding of the problem as well as an insight into other ways of dealing with the problems. Also because the building industries in other countries face the same kind of problems as in Sweden, but may have developed different ways to solve the problems, foreign articles should be studied with the hope that Sweden could learn from these experiences. The concepts that should be looked at were multifamily dwellings developed and operated by NCC, as in-house projects when NCC Housing is the customer and NCC Construction do the constructions and as much as possible of the design work. The part of the value chain that should be focused on in the research should be mainly the concept and design stages of a project. However if the same activities are carried out in other stages, they should be considered as well. Since industrialisation includes logistics and offsite production, which lie under the production stage, these should be considered as well. The operation, maintenance and demolition should not be considered in this research.

1.4 Method

Practicing a theory in real life is often said to be hard. It might be hard to express how theory is to be used or in what way the theory should be represented to best show the reality. In this part the methodology used in this research is discussed together with its limitations.

1.4.1 Case study

A case study is a research strategy to describe a complex phenomenon in a real-life context. It is used when trying to solve a problem that requires profound knowledge of the situation. (Söderholm, 2010) According to Wallén (1996) the focus in a case study is supposed to be on a contemporary phenomenon in a real-life context, which is also one advantage with this kind of study. The researcher does not have to be involved in the changing of the situation, but can just be an observer. Wallén (1996) continues that the downside of a case study is that not all situations can be studied and, therefore, one cannot know if the study can be applicable to other situations. (Wallén 1996)

This study should include a case study of one big construction company in Sweden. The chosen construction company has long experience of construction but also has most of the value chain in-house. The projects that were to be observed should be such where the company has design-build contracts that will enable the company to have control over every step in the value chain. The different projects that were to be studied should all be produced as late as possible so that the information of the grade of industrialisation is as contemporary as possible.

1.4.2 Data collection methods

The data of this research should be collected both through a literature study and through interviews and results in primary and secondary information. All three research questions should be investigated both from literature and by interviews.

In order to get a broad understanding of the process of industrialisation most aspects that have a connection to industrialisation or production strategies should be studied in the beginning. This included articles from books, journals, master's theses and licentiate theses. Information should be searched in Sweden and in Europe, especially in the UK, both to see how far the industrialisation has been developed in Sweden and to get information on the methods that are used in other countries. (Wallén, 1996)

Information about *traditional building*, *value chain, supply chain, industrialised building* and *production strategies* should be searched. When an interesting paper is read, the references then may lead to other papers that might include similar ideas in a so called snow-ball effect. In that way, ideas can be described and analysed by different researchers and a pattern can be established. (Bryman, 2002)

To be able to grasp the opinions of the interviewees, but to avoid too much structure, in-depth semi-structured interviews should be conducted. The focus of these interviews should be to see what a typical process could look like and to find out what the interviewees think is important.

There should be an interview guide with the basic questions, see Appendix, but these may be changed during the interview depending on the direction that the interview is taking. Both open ended and closed questions should be used to ensure that all information needed is gained from the interview and nothing is forgotten. The interviews should be recorded and then transcribed to allow further analysis of the answers. This should also be done to capture phrases and expressions that can be used later. (Bryman, 2002)

A good interview is supposed to fulfil criteria such as (Bryman, 2002):

- the interviewee is informed of the subject,
- the interview has some sort of structure where the interviewer describes the purpose of the interview as well as concludes the interview
- the questions need to be easily formulated
- the interviewer needs to be open and flexible during the interview
- the purpose of the interview need to be known in advance

To ensure that these points were followed during the interviews, all interviewees should be contacted in advance and given a short description of the research and the purpose of the interview. Furthermore, the questions should be discussed with two other researchers before the interviews were to be carried out, to make sure of easy

understandable questions and that nothing is to be forgotten. The interviews should also be conducted quite late in the process of the study, so that the author had as broad knowledge as possible.

The interviews should focus on how much is premade in the product development process and how much can to be adjusted in the configuration process. Furthermore, the interviews should also focus on investigating the degree of industrialisation for the concepts and to see who made the choices and in what direction the development is going for the concepts in the future. The author should choose the interviewees because of their knowledge of the concepts or processes, which is a common way to do in a case study when only having a small sample to choose from. (Bryman, 2002)

The results of the interviews should be presented using the illustration of strategies of Kok (2007) defining different production strategies in the building process, see Figure 1.2. This should be to give an overview of the product development process and what can be changed in the configuration process. Furthermore, the results concerning the different concepts should then be compared to each other as well as with the results of the literature study in order to draw conclusions and to give recommendations. The industrialisation of the different projects should be analysed with regard to Lessing's eight aspects of industrialisation.

1.5 Disposition of the report

Chapter 1 starts with an introduction to the problem that the building industry faces which then leads to the focus of the research and the research questions. The demarcations of the research are stated and the method is described.

Chapter 2 contains the theoretical framework. Here is a description of the historical building process described to see the background that has led to why the traditional building process today looks the way it does. Then the industrialised building process is described and the chapter is concluded with some of the ways to improve the industrialisation in the building process.

Chapter 3 shows the empirical results from the interviews. First is an in-house project described with its limitations and requirements and then the different concepts are described with first a general overview then, the production strategy and, last, the degree on industrialisation.

Chapter 4 here the empirical data is analysed with regard to the theoretical framework.

Chapter 5 gives an overall view of the author's own thoughts of the problem and the different solutions. Also some thoughts on the limitations of the methods chosen are presented and why the methods described in Section 1.4 was alternated in the end. Furthermore is the trustworthiness of the results discussed.

Chapter 6 summarises the conclusions drawn from the analysis and presents some recommendations that companies like NCC might find useful.

Chapter 7 Presents references referred to in Chapter 1 to 6.

2 The building industry

The traditional building process is presented in this chapter. Firstly the history of the building industry is described to give a background of how it has become. Then the whole building process is explained to describe the circumstances with its limitation, restraints and peculiarities. A part focuses on the design stages. Later reasons to why it is so hard to implement innovations in the building industry are presented. Finally, some different ways to achieve a more efficient process are discussed with the focus on the industrialisation and production strategies.

2.1 Historical building industry

Before 1850, houses were built by those who were going to live in them. In the cities some extravagant buildings were built by carpenters and masons. The state had churches, castles and channels built with help of architectural engineers. These engineers had often got their education abroad. The biggest threat to cities during this time was fires. (Nordstrand, 2003) The first sign of industrialisation in the building process came during the mid-1800s when building material started to be standardised. These materials were wood, then steel material and, at the end of the 1800s, concrete. (Lessing et al, 2005)

During the 19th century the building industry was at the leading edge of innovations and technology with symbols of the new industrialised age such as the Crystal Palace and skyscrapers (Winch, 2003). During the late 1800s, an industrial revolution took place in Sweden which led to big changes in the building process. Lots of people migrated to the cities, which led to a shortage of housing. This in turn led to poor quality buildings, quickly produced and lack of responsibilities by developers. In some cases, an architect might draw the façade but, often, no structural drawings were ever made. The construction was either on a turnkey contract or a design-build contract. Around the turn of the century some smaller architectural and also structural firms were being established. (Nordstrand, 2003)

In the first half of the 20th century the building industry was affected by both recessions and booms. Wars also caused a shortage of building materials. Plumbing and ventilation became more complicated during this time to the point where the developer no longer had enough knowledge. This led to specialists in installations and electricians emerging. Some developers had their own people experienced in installations or electricity. This led to a contract form of shared construction being used. Even architects became more important in the design process. (Nordstrand, 2003)

In USA in the 1930s a higher degree of industrialisation could be seen; for example, when Gunnison organised a house factory with a moving conveyer belt inspired by Thomas Ford. This first factory making industrialised houses was not a big success. The first totally prefabricated house was seen in Sweden at an exhibition in Stockholm 1930. (Koskela, 2003)

Since the Second World War, the idea of an industrialised building process has been discussed with the benefits of less site production, faster construction and higher quality (Koskela, 2003). In Sweden, as in many other European countries, the need for apartments was high after the Second World War (Lessing, 2006). The economic situation in Sweden after the Second World War was good, which led to that more

and more living houses were built. In 1960 the Swedish government decided that 100 000 apartments should be built each year during a ten year period, in the so called "Miljonprogrammet". These houses were mass produced with a high degree of prefabrication. (Nordstrand, 2003) This type of industrialisation focused on mass production, technical standardisation and limited choices (Lessing, 2006).

In the early 1970s, the need for apartments and small houses had decreased and industrialisation in the building industry decreased with it. Most private house construction was by way of shared construction, whereas, when the state was the customer it was a general construction. Better efficiency was demanded, especially after the 1980s following an increased usage of CAD and better usage of materials. Turnkey contracts became a more common contract form and this has increased further to date. Workers in the building industry during the 1990s started talking about the importance of quality, the environment, customer and market orientation and Information and Communication Technology. (Nordstrand, 2003)

Because of the situation with less efficiency and high costs in the building industry, the focus on industrialisation has risen again (Lessing 2006). The most recent successful industrialised building processes can be found in Japan (Koskela, 2003). Studies have shown that problems that have arisen in Japanese construction companies occur at a firm level but were the same at the project level in British construction (Winch G. , 1998).

2.2 The traditional building process today

As stated in Section 1.1 the building industry is demand-driven, fragmented and consists of peculiarities such as one-of-a-kind projects, high degree of on-site production and often temporary organisations. All of these increase the complexity and uncertainty of a project. (Lessing, 2006)

The building industry is usually highly demand-driven, as the design of a project usually does not start until a customer is placing an order (Nordstrand, 2003). There is, traditionally, nothing premade in the building industry. This can be seen as a case of close to full customisation (Kok, 2007).

As there usually are a number of enterprises in a project, working at different stages as well as involving different disciplines, the building industry is said to be fragmented (Kok, 2007). In a fragmented industry there are low barriers of entry and high competitive rivalry. This has led to "bad" competitors who can drive profit down through pricing and lower quality. The lower price and quality can then lead to work that is rushed through and to errors. (Winch, 2000) Winch (1998) continues that zero mistakes are exceptions in the building industry rather than a rule, something that Vrijoef and Koskela (2000) agree with as well.

The one-of-a-kind project is an outcome of the customers' different requirements and desires and by the differences in conditions of sites and surroundings. This kind of production is characterised by two things: the production design is part of the production process and a high degree of uncertainty. However in comparison with, for example, software programming, the degree of one-of-a-kindness is not extreme in the building industry. (Koskela, 2003)

In the building industry there is, traditionally, a high level of onsite production. The building process is built up of components and subassemblies onsite (Höök, 2005).

The site is seen as a necessary input resource for the production. There has to be production infrastructure and temporary workstations created for a specific time. This has to be planned and organised. The uncertainty of the weather is another problem where traditionally there is often a lack of shelters on the production site. (Koskela, 2003)

For each project, there is traditionally a temporary organisation of different consultants put together for that specific project. These consultants may not have worked together before and, therefore, the interaction between the different parts can suffer. The entire organisation might not be working with the project at the same time as well, which might make communication difficult. (Koskela, 2003)

Winch (2001) states that having insight into the building process will gradually decrease the uncertainty both for the customers and the construction companies. When building is more process based, the customers design parameters become process parameters (Söderholm et al. 2010). Söderholm et al. (2010) then continues that there are two different uncertainties within product development: technology novelty/complexity and project complexity. Examples of technology complexity are innovations of the technology used, while project complexity is the magnitude of interaction between the subtasks in a project. (Söderholm et al. 2010) If one subtask fails, considerable cost will be incurred, but if everything runs smoothly, savings can be made (Bilsten, 2011).

There are five different stages in the building process as in many other discrete assembly industries: concept, design, planning and control, manufacturing and assembly (Winch, 2003). Winch (2003) explains these as:

- Concept – the functionality of the product is defined.
- Design – the product is engineered and detailed, which is often captured by engineering drawings
- Planning and control – plans and control of the process of manufacturing are carried out
- Manufacturing – the transformation from raw material to discrete components and subassemblies, which make up the final product
- Assembly – the discrete components are assembled to create the finished product, often happening on site

The first stages: the concept and the design phases, of a building process have an engineering dimension, see Figure 2.1. The second part of the building process has a production dimension. It consists of planning, control, manufacture and assembly. The incentive of these parts is the material transformed from raw material to a finished product. (Kok, 2007)

2.2.1 Design process in a traditional building

The engineering dimension of the process is said to be a transformation of information from the customer's demands to a full description of a proposed technical system. This will often be developed with iterations, as a direct solution is not possible due to lack of information which comes from a high degree of uncertainty. (Jansson, 2010)

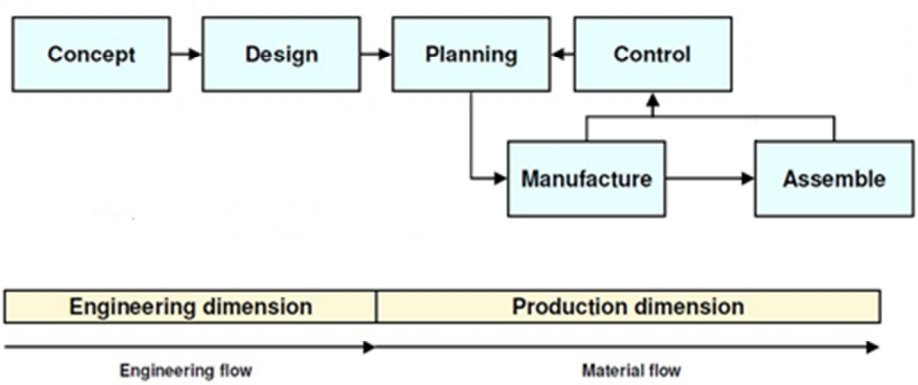

Figure 2.1. The building process (Kok 2007)

The concept phase consists of investigations as well as rough calculations of the cost and time needed to finish the project. The concept phase will result in a list of specifications that considers all the important aspects for a successful end product such as: (Nordstrand, 2003)

- Description of project
- Rooms needed
- Technical requirements
- Site investigation
- Geotechnical investigation
- Environmental requirements
- Quality requirements
- Preliminary sketches

The second stage of the process is the design phase. The design phase can be divided into three stages; preliminary design stage, the definite design stage and the detailed component design stage (Nordstand, 2003).

The first thing in the preliminary design stage is that an architect has the main responsibility to transform the list of specifications to one main alternative of the aesthetics of the house, usually with some collaboration with a structural designer and building services engineers. The concept of the building established in the concept phase should now be finalised. The outcome of the preliminary design stage should be: (Nordstrand, 2003)

- One architectural main alternative
- Preliminary structural design
- Preliminary installation design

The second phase starts after the preliminary phase ends with the architectural drawings sent to the customer for approval (Söderholm, 2010). When approved the structural system and the installations are determined as well as solutions with regard to the fire and sound requirements. A site plan is drawn and a geotechnical report is completed. Drawings showing floor plans, the façade, important sections, and some typical interior drawings are produced, as well as structural drawings of plumbing, water and electricity. At the end of the definite design stage, the following documentation should be finished: (Nordstrand, 2003)

- Description of project - general description of the selected solutions and the main reasons for the choice as well as areas and volumes
- Time schedule
- Geotechnical report
- Technical description – including choice of material
- Drawings
- Costs

When this documentation is approved and all systems and other choices are advised, the detailing of the components can start. This is where final building documents and specification of materials are shown. This phase is said to be the biggest of them all. All dimensions and positions should be determined. The surfaces and colours of the floors and the walls should be decided. The result of this phase is that the building documents consist of final drawings, descriptions and lists. These are the drawings that are going to be used when the house is built. This phase is complete when the production phase starts. The drawings needed are: (Nordstrand, 2003)

- Architect drawings (A)
- Ground drawings (M)
- Structural drawings (K)
- Building services drawings (V)
- Electrical drawings (E)
- Special drawings – may be kitchen logistics or garden drawings
- Information on quality demands, tolerances and work performance
- Lists over for example reinforcement, windows or precast elements

During all of these phases the time schedule and the predicted cost of the projects should be updated when needed. Procurements of consultants are usually arranged in the meantime. (Nordstrand, 2003)

The design process is said to be a bottleneck in the streamlining of the production process (Jansson, 2010). The purpose of the design process is to provide data to the manufacturing process, satisfy the customers' requirements and document the project with experienced feedback. In each new project the building is seen as a new item with, usually, very limited use of the experience gained from previous projects. (Jansson, Söderholm, & Johnsson, 2008)

After the design phase is finished the customers then receive tenders from one or several contractors that now get the responsibility to construct the building. As stated before, the choice of material is dictated by the consultant, but the purchase of material is conducted by the contractor that is building the house. (Nordstrand, 2003)

Some design processes are extended and there are not always the same consultants all the way through the design process. Some consultants may carry out the early investigations and other are preparing the design documents. (Nordstand, 2003)

2.3 The industrialised building process

Höök (2005) shows that the customers' general needs are control and long term quality with a low administration cost followed by fulfilment of functional demands, flexibility and good design, increased efficiency and a reduced price. One method to fulfil this is industrialisation. (Höök, 2005)

There are many ways to describe an industrialised building process. Söderholm (2010) states that it can be "focus on the interest of the entire value chain" and "long term improvement focus". It can also be described as prefabrication, long term relationship between participants and increasing use of information and communication technology tools. Lately the focus on the customer has also been considered as a crucial point. Lessing (2006) proposed this definition for industrialised house-building:

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

As presented in Section 1.1 Lessing (2006) brought up eight areas that need to be taken under consideration to accomplish a highly industrialised building process. These are:

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

A better planning and control of the process can be achieved by knowing the value chain. In this way the design, manufacturing, assembling and related processes can run more smoothly to increase efficiency. The focus should be on value adding activities and the non-value adding activities should be kept at a minimum. (Lessing, 2006) Lessing's (2006) criteria are presented in Table 2.1.

Table 2.1. Criteria for planning and control of the process (Lessing 2006)

Levels	Characteristics
0	Little structure of process planning and control. Time schedules are not definite, unclear responsibilities and management has poor control of the process.
1	A clear holistic structure of the project processes. All participants respect delivery dates and schedule.
2	Developed planning in early phases of projects where key participants collaborate to give input to schedule. Developed structure for design delivery.
3	Clearly defined gates between sub processes at which certain tasks must be fulfilled. Detailed planning of all processes supported by a structured planning system. All tasks in manufacture and assembly are thoroughly prepared for.
4	Planning and control systems supported by advanced ICT tools and integrated with planning of supply chain activities. Performance measures give important input to planning.

Developed technical systems can be achieved by usage of a more innovative design or by using platforms. The usage of these increases the efficiency of the process. These should be tested in real projects and experience should be brought back for further development of the platforms. (Lessing, 2006) Lessing's (2006) criteria for developed technical system are presented in Table 2.2 and further reading about platforms is found in Section 2.4.6.

Table 2.2. Criteria for developed technical system (Lessing, 2006)

Levels	Characteristics
0	Minimal use of developed technical systems. Hand craft methods dominate.
1	Developed technical systems are used occasionally but without a clear strategy. These may be the frame-, façade- or service systems.
2	Developed technical systems are designed and used for certain parts of the building, based on a technical strategy.
3	Complex technical systems used for a majority of the parts of the building. Systems are designed to fit to each other and developed in partnership with suppliers.
4	Complex technical systems are used, continuously developed in partnership with other participants, based on experience from projects and supported by IT tools.

In order to ensure that building components are of high quality, there should be a higher degree of off-site manufacturing of building components. This will facilitate easier control of quality, more efficient manufacturing and minimise influence of the weather, since the components only have to be assembled on the site. Furthermore will this lead to a decreasing risk of accidents due to less work on site. Lessing's (2006) criteria for off-site manufacturing of building parts are presented in Table 2.3 (Lessing, 2006)

Table 2.3. Criteria for off-site manufacturing of building parts (Lessing, 2006)

Levels	Characteristics
0	No off-site production
1	Simple parts of the building are manufactured off-site. Examples are roof trusses and concrete elements.
2	More advanced parts are pre-assembled off-site. These are, among others, façade elements, complete wall- and slab-elements and stairs with ready surfaces.
3	Advanced parts are preassembled and integrated with other preassembled parts. It can be volume elements with all surfaces completed, completely equipped bathroom modules and preassembled service elements.
4	Advanced parts are preassembled; design and manufacture are supported by IT tools, advanced logistics principles and planning system.

Long term relations between participants can be solved by partnering or similar. This will lead to participants who can evolve together and offer overall concepts to the customer. (Winch, 2000) Long term relationships between participants can also enable projects to start more rapidly (Lessing. 2006). Moreover, partnering has a tendency to exclude new entrants to the market as acting as a form of barrier to entry. New entrants cannot offer the same range of capability. Furthermore, all participants should be involved early in the process for optimisation. (Winch, 2000) Lessing's (2006) criteria for long term relations between participants are presented in Table 2.4 and partnering is further explained in Section 2.4.3.

Table 2.4. Criteria for long term relations between participants (Lessing, 2006)

Levels	Characteristics
0	No long-term relations are established.
1	Some relations are identified as more important than others.
2	Long-term relations are established with key participants, with activities to strengthen the relations. The partnering concept is used occasionally.
3	All participants are involved on long-term basis. The participants work together as a team. Strategic partnering with key participants
4	A structured programme is used to work actively to develop relations and cooperation. Evaluation is supported by IT tools. Strategic partnering is used comprehensively.

To enable less waste and better efficiency, logistics have to be integrated into the building process. This can be seen in the lean management as a 'just-in-time goal' where the right building components appear at the building site in the right quantity at just the right time. (Lessing, 2006) Lessing's (2006) criteria for logistic integrated into the building process are presented in Table 2.5 and lean management is further presented in Section 2.4.5.

Table 2.5. Criteria for logistic integrated into the building process (Lessing, 2006)

Levels	Characteristics
0	Logistics activities are not on the agenda.
1	Solutions for better materials handling are used. Sufficient storage, integrated in delivery patterns and information exchange with key suppliers are the construction examples.
2	Just-in-time principles are applied. Strategic work with low storage levels, adjusted deliveries, packages and relations with key suppliers are established.
3	Supply chain activities integrated in the building process. Developed supplier services and information flow are included, enabling advanced technical solutions.
4	Supply chain activities are fully integrated as natural parts of the building process. Supported by ICT tools for planning, purchasing, scheduling and design.

To be able to predefine the right products to the right cost, a customer focus is especially important. The building customers have been able to make changes in any direction they want, which is typical for a one-of-a-kind culture that prevails in the building industry. In many multifamily dwelling projects, the customer who buys the building is not necessarily the same as the person who uses it. Therefore the company must know what the market wants and at what price. (Lessing, 2006) Lessing's (2006) criteria for customer focus are presented in Table 2.6.

Table 2.6. Criteria for customer focus (Lessing, 2006)

Levels	Characteristics
0	The customer is anonymous and unknown.
1	General insight into basic end-customer priorities, e.g. equipment preferences, apartment size. Clear perception of who the company's customer is.
2	Basic investigations about end-customer needs and priorities for different cost levels and customer segments. Topics for investigation are, for instance, equipment, service needs and apartment layout.
3	Systematic investigations about customer needs and priorities, follow ups with tenants. ICT tools supporting investigations and analysis of the material.
4	The customer investigations and follow-ups are integrated with other areas, e.g. the technical development, manufacturing and assembly process and project planning. ICT tools make the information transparent in the whole process.

As a help to be able to plan and control the process the use of modern information and communication technology is an essential part of the industrialisation of the building process. This will help to make the information given more accurate and complete and help discover contradictions earlier in the project. (Lessing, 2006) Lessing's (2006) criteria for the use of modern information and communication technology are presented in Table 2.7.

Table 2.7. Criteria for use of modern information and communication technology (Lessing, 2006)

Levels	Characteristics
0	No ICT tools are used.
1	ICT tools are used by some participants in the process.
2	All participants use ICT tools to support their own activities. No common strategy is used.
3	All participants use ICT tools, integrated with each other. A common strategy is applied for the area.
4	Advanced ICT tools used by all participants to support other developed areas. ICT tools support and integrate design, manufacturing, planning, performance measuring and purchasing.

Industrialisation of the building process is about the use and improvement of effective methods and solutions. In order to improve the methods and solutions, systematic performance measurements and re-use of experience are crucial aspects to eliminate waste and problems in the process. (Lessing, 2006) Lessing's (2006) criteria for performance measurements and re-use of experience are presented in Table 2.8.

Table 2.8. Criteria for performance measurements and re-use of experience (Lessing, 2006)

Levels	Characteristics
0	No measurement and no systematic re-use of experience.
1	Experience exchange in some parts of the process for instance, at regular meetings with manufacturing staff or the design team. Limited documentation.
2	Measurement of tasks of some parts of the process, such as key activities in manufacturing, assembly time, follow-ups in design. Documentation is handled by individual participants.
3	Performance measurement of all parts of the process but limited coordination. Experiences well documented by process owner.
4	Performance measurement of a number of areas, experience collected and distributed systematically, with ICT tools. This supports work with the customer in focus, relations, planning and the industrial manufacturing.

These eight aspects with criteria described above make up the "Industrialised House-building Process Model" (the IHP model), which is represented by a wheel, see Figure 2.2. Lessing (2006) said that companies should strive to reach as far out on the wheel as possible in their key areas, but, as can be seen above, all of these areas are somewhat related to each other. (Lessing, 2006) Koskela and Vrijhoef (2001) reason that only optimising parts of the process without considering the consequences for the whole process often only leads to small improvements or to failure.

Figure 2.2. Industrialisation House-building Process Model wheel by Lessing (2006)

Another aspect concerning an industrialised building process is that the process seems to become more complex and vulnerable. This is because the flow is much longer, the amount planning and of design is greater, the cycle of error correction is longer and the requirements for dimensional accuracy are higher than otherwise. (Koskela & Vrijhoef, 2001)

Söderholm (2010) points out that if the building system is not well defined, the industrialised building process is most efficient with in-house resources. He continues that in order to succeed, the technology, production and business sides must work in cooperation. (Söderholm, 2010)

2.3.1 Design process in an industrialised building

Any design process in an industrialised building process can be divided into two different phases, a product development process and a configuration process. The product development process is carried out separately from specific projects and the product is then configured to meet the specific demands of the project in the configuration process. The degree of how much is adapted-to-order and how much is predetermined can differ with each process, see Figure 1.3. Depending on how much that can be adopted-to-order, the process can be described by different production strategies which are further presented in Section 2.4.2. (Callisen, 2008)

As some design work is already completed before the specific projects starts, this should lead to less time spent on the design process for the specific project. For example, certain drawings should already have been prepared and examined in the product development process. The extent of work finished in advance can vary depending upon the product. A consequence is that decisions that are usually made later in the process now instead have to be made in the early stages. This however also leads to less flexibility, when it comes to customer demands. (Callisen, 2008)

It is very important to have well designed components in an industrialised design process as there are usually fewer components to choose from. The components are used repeatedly and therefore there is less room for constant changes as in the traditional building process. (Callisen 2008)

2.4 Ways to improve industrialisation of a process

There are various ways and strategies that a company can implement to achieve a higher degree of industrialisation. Some of these ways are presented below together with some reasons why it might be hard to implement innovations into the building industry.

2.4.1 Innovations in the building industry

There are plenty of innovations of the building process but the structure of the process hinders natural ways for them to be included (Winch, 1998) (Höök, 2008). Höök argues that the building process has a deep-rooted culture that will counter-react to all changes that occur in the process. One reason for this is that substantial knowledge is tacit knowledge, knowledge that is embedded in workers. This kind of knowledge might be harder to influence than knowledge that is embedded in real capital such as machinery. Höök (2008) continues that if knowledge could be embedded in the process, a continuous learning between projects can be accomplished. Another problem with innovations in the building industry is that companies try to take a too big step when implementing changes, some of which have been seen to fail, for example NCC Komplett. (Höök, 2008)

The traditional building process has two actors that can naturally integrate innovations into the work: the main architect or engineer and the main contractor (Winch 1998). These two have the responsibility to make choices in the design and can therefore include innovations. However, since more than one can implement innovations and this might cost more money, the rate of innovation might therefore decrease. Customers should be the most important initiators of innovations (Winch, 1998) (Höök, 2006). Customers therefore need to be more technically competent to understand the innovations. Most innovations are related to technology, rather than the process. (Winch 1998) Furthermore, in the building industry, innovations have not been proved to be necessary for long term competitiveness (Koskela and Vrijhoef, 2001).

Innovations need to be of an organisational cultural change, if industrialisation is to succeed. Organisations need to have a clear vision of what they want to achieve. The change must start from the top of the organisation and all levels of the organisation must want to contribute to the change. Furthermore there must be a long-term commitment to the changes so that companies do not fall back into old procedures. Moreover to make the change appealing to the employees and customers, the innovations must be easy to communicate and understand. (Höök, 2008)

The main ways for measuring improvements are through the “iron triangle”: time, cost and quality, which might also be the most important things to influence. There are plenty of existing metrics, but none that monitor improvements in the building process well enough. There needs to be more process orientated measurements, to be able to see the benefits of the improvements better. (Söderholm, 2010)

2.4.2 Production strategies

In the traditional building process there is much focus on the customers' requirements and desires. Nothing happens in a project until the customer takes the initiative which, in project management, is seen as a concept-to-order strategy (Kok, 2007).

Winch (2003) argues that the building industry can gain most from the manufacturing industry if learning about project management. Project management can be described by where the customer' order decoupling point is situated. The customer order decoupling point is defined by Rudberg and Wikner (2004) as:

"the point in the value-adding material flow that separates decisions made under uncertainty from decisions made under certainty concerning customer demand"

The supply chain for a company can be divided into upstream and downstream from the customer order decoupling point (Guam 2012). The position of the customer order decoupling point is about finding the optimal balance between the productivity and flexibility forces. If the customer order decoupling point is positioned further upstream on the value-adding material flow, the greater is the importance of productivity with price as the major insensitive. (Rudberg &Wikner, 2004) Upstream activities are close to the raw material end, where value adding comes from transforming the raw material into standardised products (Guam, 2012). More activities must be carried out under the uncertainty of customer demand, especially as more activities are predefined. On the other hand, the customer order decoupling point on is positioned more downstream, the company will have more flexibility meeting customer demand and more activities can be carried out with better information. (Rudberg &Wikner, 2004) Downstream activities are characterised by meeting customers various needs. Upstream and downstream activities are further described in Table 2.9. (Guam 2012)

Table 2.9 Description of upstream and downstream activities from the customer order decoupling point (Guam, 2012)

Features	Upstream the CODP	Downstream the CODP
Production characteristics	Standard components, high volumes, predicable demand	Customised, high variety, wide range, unpredictable demand
Order winner	Price	Delivery speed, flexibility
Qualifiers	Quality, delivery efficiency	Quality, delivery reliability
Supply chain design	Physically efficient	Market responsive
Manufacturing task	Provide low cost manufacturing, maintain high stock availability	Manufacture to customer specification, achieve short and reliable lead times
Key Properties	Productivity	Flexibility
Improvements priorities	Cost reduction	Lead time reduction
Profit focus	Cost performance	Margin/Value contribution
Pricing model	Cost plus	Value-based
Operation problems	Cost control	Market supply

Winch (2003) model describes this with four different strategies that present the customer order decoupling point, concept-to-order, design-to-order, make-to-order and make-to-stock.

- Concept-to-order: Customers enter the project at the very beginning of the information flow and nothing happens before the customers have taken the initiative. These kinds of projects are initiated with a conceptual design.
- Design-to-order: There is already basic product concepts prepared, but design work is then carried out explicit for the unique customer and building, both pre-bid and post-contract.
- Make-to-order: Fully detailed designs are already prepared and only small configurations within certain limits can be decided by for the customer. The production does not start until the customer place an order. The flow of material is initiated when the order is signed.
- Make-to-stock: The product is made to stock without customer involvement and sold after or during construction.

Wikner and Rudberg (2004) model then add three more strategies to the chart: concept-to-stock, design-to-stock and assemble-to-order.

- Concept-to-stock: The design work begins when the customer place an order, but certain concepts are already in place, for example, by already developed platforms.
- Design-to-stock: The designs are already in place, for instance by using standardised parts and modules, but certain changes of the configurations are allowed for specific customers.
- Assemble-to-order: Use of premade standard modular components that only need to be assembled when customer place an order.

There are four customer order decoupling points that are related to the engineering dimension, and engineering work that still has to be performed: concept-to-order, concept-to-stock, design-to-order and design-to-stock. In Figure 2.3, the further to the right, the further downstream the strategy is and the more is already decided without a customer.

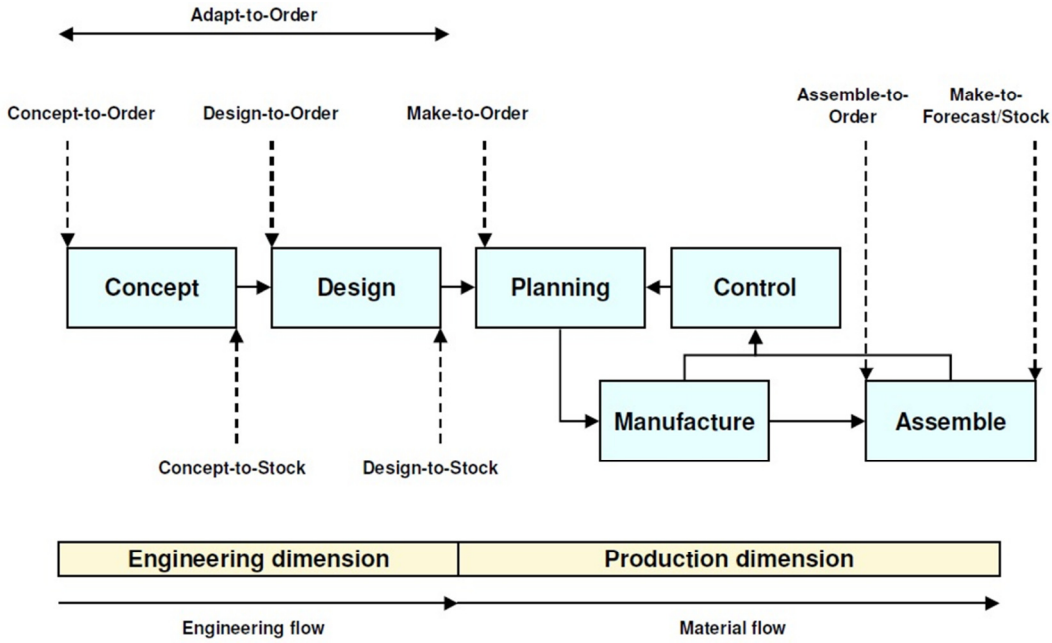

Figure 2.3. Description of the different production strategies (Kok, 2007)

The three customer order decoupling points that are related to the production dimension, where all engineering work is already performed and only production is left, are: make-to-order, assemble-to-order and make-to-stock, see Figure 2.3. Here all the engineering work has been completed and the only difference is how the production is performed. (Rudberg & Wikner, 2004) These strategies explain the relationship between the internal predefined rules of technical specifications and the external customer's demands (Jansson, 2010), in other words, the degree to which elements are finished when they leave the factory in relation to how much is needed to be completed onsite. (Bildsten, 2011)

Winch (2003) also argues that the building industry could gain considerably from moving from a concept-to-order strategy to a design-to-order strategy. Concept-to-order can be exemplified by NCC Technical Platforms (Jansson, 2010). Only in specific cases such as hotel chains, hospitals or schools, which are quite standardised building types, is a make-to-order strategy a good alternative (Winch, 2003).

A design-to-order strategy is functional when the project is unique, but even here some reputational solutions can be used (Söderholm, 2010). A concept-to-order strategy is seldom used in industrialised building, since the building system has to be designed for each new project and this is something that should be avoided. Make-to-stock involves heavy construction investments in storage and transport. Companies that rely on make-to-order concepts compete with the efficiency of their organisation as their main argument. On the other hand, companies that offer design-to-order solutions have to be very flexible to be able to meet various customers' demands. Companies that offer both design-to-order and make-to-order solutions have to be both efficient and flexible. In such companies, technology, labour and production have to be efficient. This works against flexibility, which makes it difficult for companies to combine these two strategies. Companies can only be good at these two strategies at the same time, if they have separate divisions that focus either on efficiency or flexibility. (Söderholm et al, 2010)

2.4.3 Partnership

One way to change the building industry is through procurements. These should be based on performance and not cost. Another way is through the operational process. (Koskela, Ballard, & Howell, 2003)

If actors are not equally responsible for the increase of the total value and reduction of the total costs, they are most likely to favour their own part. Each actor tries to reduce the cost for their own part, which sometimes increases the cost for other parts and maybe also the total cost. (Höök, 2008)

One solution to this problem is said to be partnering (Höök, 2008). There are two different types of partnership (Winch, 2000):

- Single project partnering: The parties form a partnering for one project to benefit by openness and minimising differences.
- Multi-project partnering: Partnership that benefits from long term relationships and moving forward together.

When entering a partnership with another company it is important to mutually share information. Especially in multi-project partnering is sharing information about each other's costs and processes important as well as information of how to achieve production efficiency. (Bildsten, 2011)

2.4.4 In-house projects

An in-house project is where one company is doing everything from buying the land and planning the project all the way to finishing the house, see Figure 2.4. These kinds of projects can be seen to be on a design-build contract contrary to the more common design-bid-build contract. In these kinds of contracts the contractor takes full financial responsibility. The plan is usually then to sell the house when it is completed or during the production to an external buyer. When the house is sold, the production then becomes a normal contract. (Révai, 2011)

This is the usual contract used when contractors build houses. This kind of contract is explicit from a planning point of view. As the contractor is part of the project from the very beginning, the planning work becomes easier. The planning of the whole project can be carried out from start and decisions even about production can be taken early. (Révai, 2011)

The typical process of an in-house project:

- The company gets an idea of a suitable project
- Some investigations are carried out such as suitable site options
- The company either owns or buy a site
- The funding is secured
- The design for the product is performed
- The planning of the building is performed
- The construction of the building is completed
- The project is finished and either sold or administrated

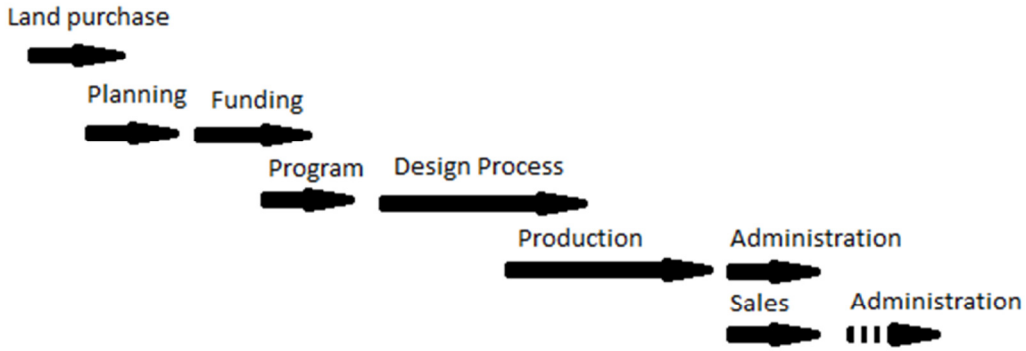

Figure 2.4. Example of building process in case of design-build contract (from Nordstrand, 2003)

When having these kinds of projects, the construction company generally gains higher profits, especially where the demand for houses is higher than supply. Another major gain, when having design-build contracts is that all experience from a project stays in the company and can be used in later projects. (Révai, 2011)

Two of the major construction companies in Sweden are more focused on the design-build procurement of construction. These contractors have single contracts with the customer for both design and construction. (Lessing, 2006) Studies have shown that the cost difference compared to the traditional design-bid-build contract is not big, but that the total delivery time is around 30% shorter. It is said to be faster because the time for bidding is removed, the contactor has bigger influence over the design and design and construction can more easily be overlapped, which give shorter production time. (Koskela, 2003)

2.4.5 Lean production

Lean production is defined as improving flow and smoothness to eliminate waste and to produce a higher customer value. In lean production, there are five accompanying principles: (Höök, 2008 and Söderholm, 2010)

- Value: Value can only be defined by the end user, not necessarily the customer.
- Value stream: All operations and activities required to give the end user the right value.
- Flow: There must be a flow between operations and activities according to the value and the value stream. All other things are waste and should be reduced.
- Pull: The operation should start when the customer asks for it
- Perfection: Companies need to work with all of the four steps mentioned above in order to reach perfection.

When implementing lean production into a company the work flow has to be defined through a value stream. Mapping visualises every step from buying raw material to the finished product (Bildsten, 2011). Bildsten (2011) then continues that to eliminate waste, everyone has to be informed about the work flow to be able to correct defects. One reason for this is that the root of most waste and problems comes from a stage of the process other than where it is found (Vrijhoef & Koskela 2000).

Höök (2008) argues, though, that the lean production concept is very fragile and only works as long as everything runs perfectly. When implementing lean production into

the building process the focus has to be on the quality needed, the production flow and efficiency and flexibility is kept at a manageable level. (Höök, 2008)

One of the best known parts of the lean production is the concept on 'just-in-time' logistics. This means that the right parts should be provided in the right amount just when they are needed in order to have as little inventory as possible. Implementing these logistics into the process should lead to less waste and a faster process. (Lessing, 2006)

2.4.6 Platforms

In order to be able to meet customers' demands of flexibility, both in technical solutions and manufacture, companies may develop technical platforms (Jansson, 2010). This is performed such that the company can gain from economies of scale by standardisation (Thuesen & Hvam, 2011). The use of platforms originates from product-based industries employing make-to-order production strategies, but is rarer in project-based industries. As can be seen from previous studies, it is easier to have non-value solutions and interfaces between components. A successful platform must also be "tailored to an existing business". The platforms need to be well documented and easy to comprehend, especially when working with external consultants. (Jansson, Johansson, & Engström, 2013)

A product platform contains the assets components, processes, knowledge and relationships. The platform should be applied in the design phase and thereby prevent project based solutions. The product development, production, logistics processes and organisational structure as well as the knowledgebase to manage the platform are all influenced by the platform. (Jansson, Johansson, & Engström, 2013)

The component part of the platform is that which can be altered to have a changeable end product. It should contain solutions that represent the kind of products that the company is producing and the demand of the customer. (Thusen and Hvam, 2011) The solutions should be tested on full scale projects (Lessing, 2006). When using a component part of the platform, the design work and specialised solutions should be minimised for the specific project and, therefore, efficiency should increase. There must be flexibility between the standardisation and the customers' demands. (Thuesen & Hvam, 2011) This can be achieved through a combination of commonality, common parts that are present in every project, and distinctiveness, which then makes the project unique. (Jansson, Johansson, & Engström, 2013) However, there is a strong antipathy in the building industry against standardised solutions and off-shelf design (Jansson, Johansson, & Engström, 2013), projects that follow strategies such as design-to-stock, make-to-order, assemble-to-order and make-to-stock.

The process part of the platform should be based on the main process in the company. The process part of the platform should be a support to the overall technical platform and can include modules for logistics, collaboration, customer investigations and information flow. (Lessing, 2006) The routines of how to use the solutions should be standardised in order to obtain maximum efficiency. The standardisation should be based on the best way to perform a task and should be performed in the same manner irrespectively of who handles it. If this is accomplished, measurements of improvements of solutions can be performed, especially when something in the process changes. (Höök, 2008) To have a well-developed standardisation of the

process means that reduced time is spent on coordination and information search during the design phase (Söderholm, 2010).

The knowledge part of the platform is the mechanism to combine the standard with the flow of knowledge. The relationship part of the platform is the relationship between the people working with the platform as well as the relationship with other companies. (Jansson, Johansson, & Engström, 2013)

The platform should be continuously developed and improved according to the experience from revision projects and development of new solutions. An example of this can be seen in Figure 2.5 where the component part of the platform (the technical platform and the process part of the platform is continuously developed and integrated from each other as well as developed by the experience from the projects that are carries out. (Lessing, 2006) The development of the platform should be separated from the everyday work to control its progression (Thuesen and Hvam, 2011).

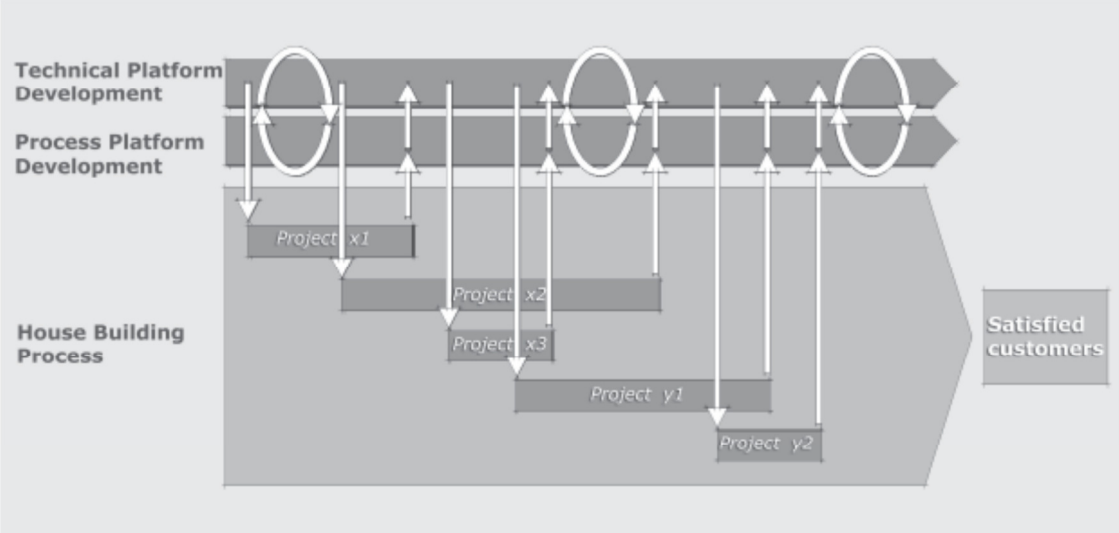

Figure 2.5 Example of how a platform can be optimised through iterations and experience from projects. Lessing 2006

In order to limit the risk that the project unique solution otherwise would cause the platform to degrade, it is important to have good supporting methods for engineers to satisfy customer requirements. (Jansson, Johansson, & Engström, 2013)

3 Case Study

In this chapter the general process for in-house projects is described followed by a description of selected concepts and the result of interviews concerning each concept. The results are divided into production strategy and degree of industrialisation.

3.1 The process for in-house projects at NCC

An in-house project at NCC is initiated by the developer division NCC Housing, which executes the project with NCC Construction. NCC Housing has the responsibility from buying of land to selling of the finished single or multi-family dwellings. One project like this can take 5-6 years to execute. NCC Housing then contracts NCC Construction to carry out the production. It is usually the subdivision NCC Engineering that undertakes the design works in the projects. (Forseström, 20/05/13)

The first priority for NCC Housing in initiating a project is to convince the municipal authority to commence preparation of a detailed development plan over the area. Representatives from NCC Housing attempt to influence the municipal authority to plan the area in a way that NCC Housing knows will be conducive to the construction and sale of apartments. To ensure this the NCC Housing representatives must determine what multifamily dwellings will sell in that specific area. During this time period, the project manager starts the preliminary design phase, together with an architect. All conditions and restrictions have to be known before they can start with the drawings and many of the restrictions come from the detailed development plan. Consultation with NCC Engineering will occur, if it is a complicated project. If any aspect of the preliminary designs of the multifamily dwellings does not agree with the detailed development plan, the project manager must request the municipal authority for a deviation from the plan, which takes additional time. Appeals will usually delay the project for a couple of months. All intended roads in the area have to be determined and the official roads have to be awarded at a public tender before any ground work can start for the multifamily dwellings. Once the detailed development plan becomes final, it is expected that ground work can commence within the following twelve months. (Forseström, 20/05/13)

The definite design stage starts when most aspects of the architecture of the house and the general idea of the structural system have been decided. NCC Housing still has responsibility over this stage, due to the fact that NCC Construction lacks design managers. The definite design drawings are the basis of the contracts with the temporary owners of the multifamily dwellings, which NCC Housing has administrated as well as the selling material for the apartments or small houses. From the start of the definite design stage, the consultants sit together one day a week designing in so called collaborative design to make the design phase running easier. (Forseström, 20/05/13) This is NCCs version of the Big Room concept. All the consultants are obliged to participate in the collaborative design. (Forseström, 20/05/13) It is said to increase the feeling of being part of a team (NCC.se, 2013) as well as validate deliveries and ensure constructability (Jansson, Johansson, & Engström, 2013). The collaboration design day follows a set agenda, with scheduled meetings in the morning, after lunch questions are answered and decisions can be taken concerning the problems in the project (Forseström, 20/05/13). The design time

has not been significantly reduced when using collaborative design at NCC, but more problems are solved before production starts (Jansson, Johansson, & Engström, 2013).

NCC Construction may commence ground work when over 50 percent of all apartments have been sold. Not all detailed component designs has to be ready at this stage but the significant parts like foundation, structural system and roof must be determined, so that the internal procurement team can buy the materials. The detailed design stage also usually takes longer time than scheduled. NCC wanted to have a more elaborate definite design stage so that not as many changes were made in the detailed design stage to better ensure that the selling material was accurate. It was said that this should reduce the detailed design work, but this has not happened (Forseström, 20/05/13)

Therefore, NCC Housing would like to use more finished concepts to minimise the overall time of a project. In particular, they wish to reduce the design time, as more demands and classifications are other reasons for delays. This means that NCC Housing needs to sell the finished concept during the detailed development plan process, if the concept is to be used. However, in more urbanised areas, these concepts usually not agree with what the municipal authority approves for that area and they are therefore rejected. (Forseström, 20/05/13)

3.2 NCC Technical Platforms

Figure 3.1. Example of how a house for which NCC Technical Platforms have been used can look like (Bostäder Tölöbergs Terrass etapp 1 , 2008-2014)

NCC Technical Platforms is a concept of prepared methods and solutions that can be integrated and adapted for specific projects (Haglund, 2010), see Figure 3.1 for an example. The platforms are more focused on components and knowledge and have less focus on processes and relationships (Jansson, Johansson, & Engström, 2013). The platforms for apartments and single family houses consist of directorial design demands, examples of drawings, documents to support the design process and a way for feedback of experience (Haglund, 2010). The platforms are intended to shorten the

construction time, minimise errors, gain economies of scale when standard products are used and improve the experience in the company. There are technical platforms for the structural system and installations (Pfiffer, 21/05/13). The outline of the apartments is not explained in NCC Technical Platforms (Forseström, 20/05/13). NCC Technical Platforms consist of: (Haglund, 2010)

- Joined parts, when it comes to sound insulation class and choice of wet areas
- Principles for ground work describing excavation and filling
- Substructures
- Building carcass
- Roofs
- External walls
- Room formation
- Internal surface layers
- Installations

The technical solutions in the platforms are well known in the organisation (Haglund, 2010). One problem with the solutions has been that they not always fit each other and because of this, have been hard to use. This is something that NCC now are trying to remedy in a so called "platform meeting building components project" (plattformsmöte byggdelsprojekt), where people from procurement, NCC Housing, production and design managers sit and discuss each separate building components to make sure that optimal solutions are represented in the NCC Technical Platforms. This work is planned to take a few years, but should result in drawings, for example, information about work performance and templates to help with purchases in the NCC Technical Platforms. All finished solutions are premade in Revit. (Pfiffer, 21/05/13)

The preliminary design has to be checked against the NCC Technical Platforms to make sure it follows the guidelines of the platforms. The NCC Technical Platforms should always be used unless it is something restricted by the detailed development plan. (Forseström, 20/05/13) A further description of NCC Technical Platforms is presented in Table 3.1.

Table 3.1. Description of NCC Technical Platforms

Description of the NCC Technical Platforms	
Type of house	One for single family dwellings and one for apartments
Characteristic	Known solutions
Number of stories	Project unique
Apartments at each floor	Project unique
Façade	All
Type of structural system	Timber, concrete or steel
Standardisation	A few different types of each building components

3.2.1 Production strategy

The NCC Technical Platforms should be used from the very start of the project, but it is primarily in the definite design phase where they are useful. The later a solution is decided in a project, the harder it is to use the NCC Technical Platform. Pfeiffer (21/05/13) considers the premade solutions to be very time efficient, allowing more time to be spent on the components that are not yet in the NCC Technical Platforms. (Pfeiffer, 21/05/13)

NCC Housing always wishes to use for example standard stairwells and elevators in in-house projects (Forseström, 20/05/13) so that the height is always consistent for each floor. Exceptions to this include, for example, retail shops on the ground floor, which need to have a different height than the standard. (Pfeiffer, 21/05/13)

A preliminary design stage can take around two to six months, but as it usually is performed in parallel with the detailed development planning process, the timing is typically extended to the same length, which takes no less than one year. The architects then have to make point operations during this time. A definite design stage should take around four to six months and detailed design stage is around five months. The definite design stage and the detailed design stage should together take no more than one year to complete. (Forseström, 20/05/13)

3.2.2 Degree of industrialisation

NCC Housing attempts to have the same process for all their projects. There is a specific way in which the folders are organised for each project and there are templates for content and when they should be sent to the NCC board or the municipal authority. However, due to the uniqueness of each new project, it is hard to have full control of the process. (Forseström, 200513)

The building components in the NCC Technical Platforms are all tested in real projects (Haglund, 2010). The building components follow Bygghandling 90 and the BSAB-system for installations. All solutions are prepared in Revit. However, because all building parts do not fit to each other, and further, because not all kinds of building components are included in the platforms, the system cannot be used to its fullest extent. (Pfeiffer, 21/05/13)

The degree of prefabrication varies from project to project and depends on the cost. To use more prefabrication, the production of the multifamily dwelling may be finished earlier but could result in a higher cost. Another uncertainty with prefabrication is whether the prefabricated components can be delivered on time. However, there are no standards to use prefabricated components in a project, nor are there standards for the logistics in the projects. (Forseström, 20/05/13)

NCC Construction has made the strategic choice to work only with some external consultants. Among these, there are four different architectural firms, who are supposed to know the NCC Technical Platforms. However, there is a risk that if another architect has been working with the detailed development plan, this firm may be continued to be involved in the project. NCC Housing is also trying to work together with NCC Engineering as much as possible and always with NCC Construction. However, other consultants may be consulted on specific questions or if NCC Engineering does not have the time. (Forseström, 20/05/13)

Neither the temporary owners nor the end users have anything to do when making decisions about the multifamily dwellings as for example the design are decided on in early stages of the project by NCC Housing. They all enter the project too late. This means that NCC Housing must anticipate what the market wants in this area. To get feedback about these decisions and inform future choices, the customers receive a survey to answer after a project is finished. (Forseström, 20/05/13)

There is also a mailbox where workers at NCC can give comments on the NCC Technical Platforms. These are reviewed and logged for further improvements. Furthermore, a group of people working with the development of the NCC Technical Platforms meets with the site manager to discuss the finished project. (Pfeiffer, 21/05/13) However, all solutions in the NCC Technical Platforms have to be questioned to make sure that they are the right ones to use and that are not too expensive (Forseström, 20/05/13).

3.3 NCC Folkboende

Figure 3.2. Example of what a NCC Folkboende house could look like ((Produktbeskrivning NCC Folkboende, 2013).

NCC Folkboende is a concept of a four to eight stories point block that was initiated in 2009, see example Figure 3.2 (Produktbeskrivning NCC Folkboende, 2013). Careful planning, innovations and traditional craftsmanship have led to the construction of efficient and low cost multifamily dwellings. The design was made with the help of NCC Technical Platforms, where only standard solutions were used. The structural system, including balconies, staircases, columns and edge beams, are all made of concrete cast on site. The apartments can have three different interior wall colours. NCC Folkboende is considered as a low energy house. There are premade documents and drawings that only need adjustments for each unique project. All changes made from the original drawings should be approved by the NCC Folkboende Project group, which acts as support for the local organisations handling the projects. (Karlsson, 13/05/13)

The concept was initiated by a group of well experienced contractors, who wanted to use the best, most efficient technique to build multifamily dwellings at a responsible price. The result was a point block with no less than four stories and no more than eight stories, with a choice of one, two or three room apartments. The focus was to get

an easy production with the right material. One example of this is the onsite cast concrete structural system that is used to hide the installations to save space and improve fire safety and sound quality. Using well known techniques that allow for continuous improvement was important. Description of NCC Folkboende multifamily dwellings is presented in Table 3.2. (Karlsson, 13/05/13)

NCC Folkboende still has the same problem as other point blocks with no silent side, as there are bedrooms on all fours sides, see Figure 3.3. Another problem the project group now is trying to solve is that not all municipal authorities have emergency rescue vehicles for a height of eight stories. Therefore, some municipal authorities cannot approve buildings higher than the normal height for rescue vehicles of five stories. (Karlsson, 13/05/13)

Table 3.2. Description of NCC Folkboende

Description of the concept NCC Folkboende	
Type of house	Point block
Characteristic	Production friendly product, Low energy house
Number of stories	Four to eight
Apartments at each floor	Four to six
Façade	Brick
Type of structural system	On site cast concrete
Standardisation	Shape of house, roof, few door and window options, standardised bathrooms

3.3.1 Production strategy

The design work in NCC Folkboende is a continuing process. There are detailed drawings over each floor except for the ground floor, which still has to be designed by the consultants. Ground drawings have to be made specifically. There are about eight different types of main plans for the rest of the house. These plans only need to be reviewed, but are set to the point that the interior can be chosen. The drawings from projects using a unique solution will be saved and ready to be used again, which will lead to even shorter design time in the future. (Karlsson, 13/05/13)

Figure 3.3. Examples of how the outline of a floor for NCC Folkboende could look like.

The production of one NCC Folkboende multifamily dwelling in a project takes around twelve months, whereas the production for two houses produced at the same time takes fourteen months. (Karlsson, 13/05/13)

3.3.2 Degree of industrialisation

In the concept of NCC Folkboende, the guiding documents are supposed to be followed to ensure a good result. All stages are developed from experience and then documented, so that the supposedly best processes are used. There is also a reference project to look at that can act as a guide. (Karlsson, 13/05/13)

The structural system of NCC Folkboende comes from the standard solutions in the NCC Technical Platforms and includes no special solutions. These are well tested in real projects. (Produktbeskrivning NCC Folkboende, 2013) The houses are of concrete cast on site. Some of the structural system is precast on the building site, such as, for example, the stairs and balconies. (Karlsson, 13/05/13)

Consultants contracted for the architecture, installations, structural system and electricity have all been part of the team that has worked with NCC Folkboende since the beginning. The same consultants are contracted for every NCC Folkboende project in a long term partnership. There are also consultants contracted for groundwork, fire safety and sound insulation, but, if possible, local consultants will be used for these aspects. (Karlsson, 13/05/13)

Guiding documents support with the logistics on the building site, but it is the local organisation that is responsible. All guides and plans also exist with the use of Information and Communication Technology tools. There also exist 3D models that support sales and marketing of the apartments. However, as a local organisation handles the projects, there is no guarantee that the guides are used or followed. (Karlsson, 13/05/13)

There was no customer in mind when NCC Folkboende was established. Karlsson (13/05/13) points out that the focus was on what the market needed and how this was accomplished in the best way based on experience. However, some solutions were tested in the multifamily dwellings built in Umeå, before they were decided to be used in NCC Folkboende. (Karlsson, 13/05/13)

The NCC Folkboende Project group and the local organisation discuss the outcome of each project when it ends. All experience is logged and reviewed annually. (Karlsson, 13/05/13)

3.4 Kuben

Figure 3.4. Examples of how an area with Kuben could look like (KUBEN Koncept för energieffektiva småhus, 2013)

Kuben is a concept of detached, semidetached or terrace houses that can be combined to make a living area, see Figures 3.5 to 3.7. An area with Kuben could like Figure 3.4. The houses are intended for families with children and for people over 55 years. (KUBEN Koncept för energieffektiva småhus, 2013) They were intended to be production friendly and to have good energy values. It was established as a concept primarily by workers from NCC, from Gothenburg and from Malmö. Some brokers were involved in the process to make sure that the house was what the market wanted as well as one architect from Malmö and one from Gothenburg to work on the layouts and the drawings. The people from Malmö and the people from Gothenburg did not agree on everything in the end due to regional differences and Kuben became a concept that was established in Gothenburg. The concept was on the market by the end of 2010 (Edling, 22/05/13). These houses are designed on the basis of NCC Technical Platforms (KUBEN Koncept för energieffektiva småhus, 2013).

There are usually no less than 16 houses but the optimal is around 60 houses for an individual project. The house is made to fit in all types of areas but due to the low production costs it was thought it would be best used in areas outside the centre of a city, where the production price is usually higher than the revenue. (Edling, 22/05/13) All drawings and building documents are premade and ready to be used. The house comes in two sizes and the façade material and the shape of roof can be varied so that the houses can fit into more areas. The structural system is made of a wooden frame. (KUBEN Koncept för energieffektiva småhus, 2013) Further description of Kuben is presented in Table 3.3. Further development of Kuben is concern a better marketing, to make a passive house alternative for the 120 square meter house and to make distribution material for the semi subterranean house (Edling, 22/05/13).

Table 3.3. Description of the concept Kuben. (KUBEN Koncept för energieffektiva småhus, 2013)

Description of the concept Kuben	
Type of house	Detached, semidetached or terrace houses, 120 or 140 square meter in size.
Characteristic	Cube shape to be easy to produce and energy efficient, premade for solar heating. Intended for families and people over 55 years
Number of stories	Two
Apartments at each floor	One
Façade	Brick, wood panels or plaster
Type of structural system	Wood frame, slab on ground or on piles
Standardisation	Standard bathroom, two roof alternatives, three façade alternatives

Figure 3.5. Kuben as detached houses

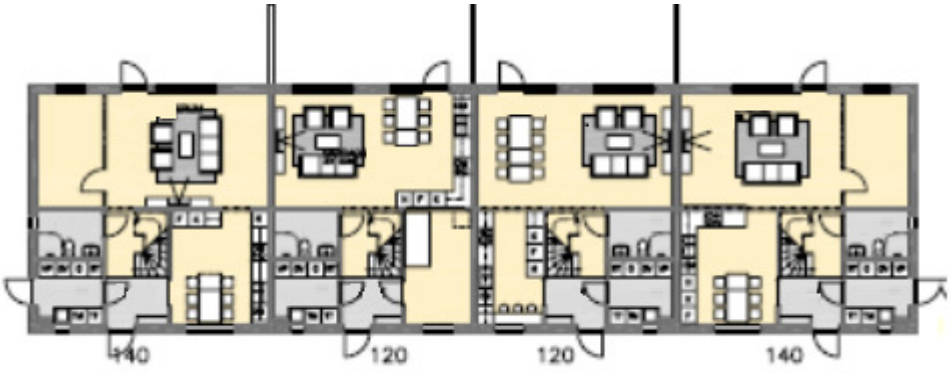

Figure 3.6. Kuben as terrace houses

Figure 3.7. Kuben as semi-detached houses

3.4.1 Production strategy

There exist some different varieties of Kuben. The house can either be 120 square meters or 140 square meters in size. It can either come with mono pitched or a pitched roof and, as mentioned above, the houses can have different façades made of wood panels, bricks, board material or plaster. The materials for the walls behind the façade are the same for all options. All drawings are completed and ready to be used for the brick or wood alternative. Although some drawings are lacking for the other two materials, as Edling (22/05/13) mentioned, as soon as they are finished, these alternatives will be completed as well. Even the ground drawings are premade, with either a slab on the ground or a slab supported by piles. There also exist 3D models, cost plans, time schedule and calculations over the energy needed in the worst case scenario. (Edling, 22/05/13)

The larger 140 square meter house also exists as a passive house alternative where everything is already prepared. This alternative was a result from demands of a customer where only minor alterations had to be made to the original sketches. Edling (22/05/13) also mentioned that the best thing with having a concept is that even though the customer wants to have changes made from the original sketches, one can agree on a price much sooner than usual. The production time is six months for one house and then four more houses can be finished each month for an area with Kuben after the ground work is completed. (Edling, 22/05/13)

3.4.2 Degree of industrialisation

There is no pre-determined process for the design and construction in the Kuben concept. This is because the production techniques will change depending on what is most suited to the building site of each project. If possible, it is preferred to build the houses on site as this will cost less. However, if for any reason this is not possible, the houses can also be pre-made in factories. Nevertheless, the process has the potential to be controlled and repeated. (Edling, 22/05/13)

New technology had to be developed, given the intension for the Kuben to be very energy efficient. The exterior wall used for Kuben was taken from an old version of the NCC Technical Platforms for multifamily dwellings, but is now used in the NCC Technical Platforms for small houses and a consequently available for Kuben. Old

heat pumps had to be changed for new more efficient ones and a FTX system, which is normally not used in small houses, is used here. All of this was decided to meet new requirements that were set by the municipals or ones that are expected. There are also 3D models to show the concept in early stages. (Edling, 22/05/13)

The architect from Gothenburg originally involved in the design of the Kuben concept is still contracted in a long term partnership to work on each new project whenever needed. Some of the people that worked on the installation are still used for the development of the concept. (Edling, 22/05/13)

The logistics during the building process is to purchase all material at the beginning of the construction and then have each material delivered one week apart. When the whole house was premade, one house was delivered to the production site to be assembled each week. Accordingly, there is no specific process included in the concept when it comes to logistics. There is one person in Gothenburg that makes all the purchases of materials for the Gothenburg area. If a project should be in another part of the country it is intended that a local person makes the purchases for that project. However, most of the purchases can be made using NCC standard agreements. (Edling, 22/05/13)

The market was involved by the broker and by NCC Housing during the development of Kuben. For each project the end user may make some choices to individualise their house, depending on how much the customer wants to lock in the beginning of design. (Edling, 22/05/13)

People working with Kuben are still such a small group that information can easy be shared between them. The projects executed are all around the Gothenburg area, so for each new project it is easy to visit previous built production site. It might be harder to maintain a good reuse of experience if the concept is growing bigger as there is no documented process for sharing of experience. (Edling, 22/05/13)

3.5 P303

Figure 3.8. Example of how a two storey P303 house could look like (Produktbeskrivning P303 Tvåvånings Flerbostadshus, 2012).

P303 was originally developed by NCC, together with White architects, for example see Figure 3.8. The main focus was on the price to the end customer. (Produktbeskrivning P303 Tvåvånings Flerbostadshus, 2012) P303 was established as

a result from several market analyses where macro factors, such as what the market needed and not what the customer wanted, were investigated. This was performed to find out the reasons that made the cost for multifamily dwellings rise and why so few multifamily dwellings were being built in Sweden. The first project using the concept P303 started the production in 2010. There are still only a limited number of people at NCC working with the administration, development and sales of projects using the P303 concept, but the production is carried out either by them or by local NCC offices. (Lindblad, 07/05/13)

P303 is said to be a concept with an efficient process of constructing multifamily dwellings with a high level of standardisation. The houses can be either two or four stories high. Each house comprises of at least two units where each unit comprise of two identical apartments on top of each other. These can then be combined differently to create an outdoor space. The kitchen and wet areas make up the core of the unit. Further description of the P303 concept can be seen in Table 3.4. Production of multifamily dwelling in P303 is performed on site where the structural system is made out of onsite cast concrete. There can be different materials and colours of the façade and different shapes of roofs to create variation. All drawings are premade and the building process is systemised to enable a quick production. In P303 no changes, additional work or outgoing work are allowed. (Lindblad, 07/05/13)

Today the original version of the two storey house has been replaced by a new two storey version and a four storey version as a result based on feedback from the owners of more than 100 apartments that have been built using this concept. The system used should be able to follow the requirements of as many municipalities as possible but does not always meet the special requirements of some municipalities. A unique solution is then usually not made, which means that P303 cannot be used there. In the future, the team behind P303 wants to develop more fashionable apartments from the concept or use the production technique and the process in ad hoc projects as well. (Lindblad, 07/05/13)

Table 3.4. Description of the concept P303. (Produktbeskrivning P303 Tvåvånings Flerbostadshus, 2012)

Description of the concept P303	
Type of house	Apartment house
Characteristic	Two identical apartments on top of each other.
Number of stories	Two or four
Apartments at each floor	Depending on how many units are put together
Façade	Brick, wood panels or plaster
Type of structural system	On site cast concrete
Standardisation	Everything

3.5.1 Production strategy

All drawings except for the ground work are finished for the multifamily dwellings in P303. These were completed in the production development process. The two storey

house has three different types of apartments which can be alternated, as long as there are the same kinds of apartment on both floors. The four storey house has three different apartments, which cannot be alternated. There is also a description of the building process, a set time schedule and cost plan. (Lindblad, 07/05/13)

The ground work is performed uniquely for each project. When this is completed, the rest of the design work is said to take four hours from sketch to finished house, where the only things that are not standardised are colour and material of the façade and roof material and shape. This means that nearly the whole design process is completed in the product development stage. The production of the multifamily dwellings in P303 then takes around six to nine months for the house production and around two months for the ground work. (Lindblad, 07/05/13)

3.5.2 Degree of industrialisation

P303 is said to be a highly industrialised concept. There is a highly planned and controlled process. P303 has been established on well tested technical systems. It has a medium degree of prefabrication as, for example, the structural system is made of onsite cast concrete, but the bathroom and kitchen are prefabricated. A description of the product, detailed planning plans, 3D models, schedule, and cost plans have been developed. (Lindblad, 07/05/13)

Some of the original consultants are still working with the development of the concept but other have been replaced, so to some degree there are long term relationships included in the process. The majority of the materials used are purchased under standard agreements by one person working on all P303 projects. This also means that he has the experience to determine when materials are needed on the building site, so that ‘just-in-time’ logistics are used as much as possible. (Lindblad, 07/05/13)

The system was developed on the basis of market analysis of what the market indicated it would need. The individual customer cannot choose anything in the multifamily dwellings. All feedback from old projects is logged and can be shared as there are only a small number of people working in all P303 projects as well as with the development of the concept. (Lindblad, 07/05/13)

4 Analysis

The results provided in Chapter 3 are analysed in this chapter according to the theory presented in Chapter 2. The production strategy is considered in light of the product development process and what is performed in the configuration process described in Kok (2007), see Figure 1.2. Then each concept is evaluated according to the eight aspects set out in the industrialisation wheel according to Lessing (2006), described in Section 2.3. Finally, the concepts are compared and contrasted to each other.

4.1 Design process versus industrialised design process

The design process in a project takes more and more time. Much of the time seems to be spent on waiting for the municipals to finalise the detailed development plan over the actual area. However, this aspect is outside the scope of this thesis. Time delay is also attributed to the increasing number of requirements to meet and classifications to complete and all of this can be performed more efficient and reliable with the usage of more Information and Communications Technology tools. As one of the interviewees pointed out, even if you improve one design stage, it does not seem to shorten the time for the next design stage (Forseström, 22/05/13). Furthermore, the time spent on designing the house could be shorter if more standard solutions could be used, which is something that all the interviewees seem to agree to.

The market is traditionally used to one-of-a-kind projects and procurements on a concept-to-order basis. The customers are accustomed to ordering tailored design, which does not encourage repetition in the process. The concept-to-order mission therefore has important properties handling risk that the other strategies lack (Winch, 2003), as money and time are only spent on what is wanted. Furthermore, as one of the interviewees pointed out, it is not until you know the process and the production techniques that one can decide on improvements (Karlsson, 13/05/13).

NCC Technical Platforms can, particularly after the redesign of the platforms is completed, be seen as a concept-to-stock strategy because there are premade solutions of all the standard building components that are intended to be used. See Figure 4.1 of where the customer enters the value chain. However, most of the design work still has to be performed for each new project.

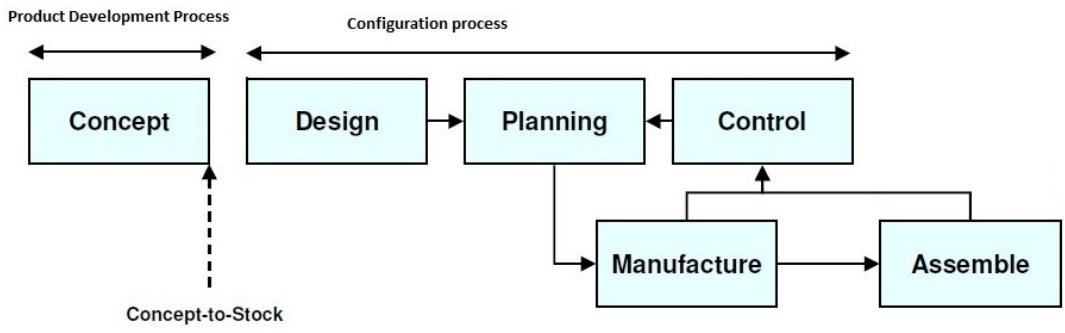

Figure 4.1. Description of the design process when concept-to-stock strategy is being used (from Kok, 2007).

Söderberg et al (2010) argue that a highly standardised building is beneficial in terms of optimising the design, but it is also more difficult to find customers. On the other hand, excessive flexibility makes it more difficult for continuous improvement of the

process and also contradicts economies of scale. (Söderberg et al, 2010) This is something that can be seen in, for example NCC in-house projects, where the NCC Technical Platforms are not used and therefore standard components cannot be used due to that extra offer of flexibility.

As described in Section 2.3.1, an industrialised building design process has two different phases: one product development phase and one configuration phase (Callisen, 2008). Winch (2003) argues that the first challenge should be to move towards a design-to-order strategy, see Figure 4.2, where more system integration offer modularised solutions engineered to meet the customers' particular needs on a turn-key basis. The production strategy of NCC Folkboende can be seen as design-to-stock, as premade designs exist which only need to be reviewed for each new project, see Figure 4.2. There is almost no design work needed for floor two and upwards. The only work to be completed is to choose the configuration of apartments that is desired on each floor. However, as for the ground floor, it is more of a design-to-order strategy, see Figure 4.2. Many parameters, for example the size of the house, are already set, but the layout of the ground floor still has to be decided. (Karlsson, 130513)

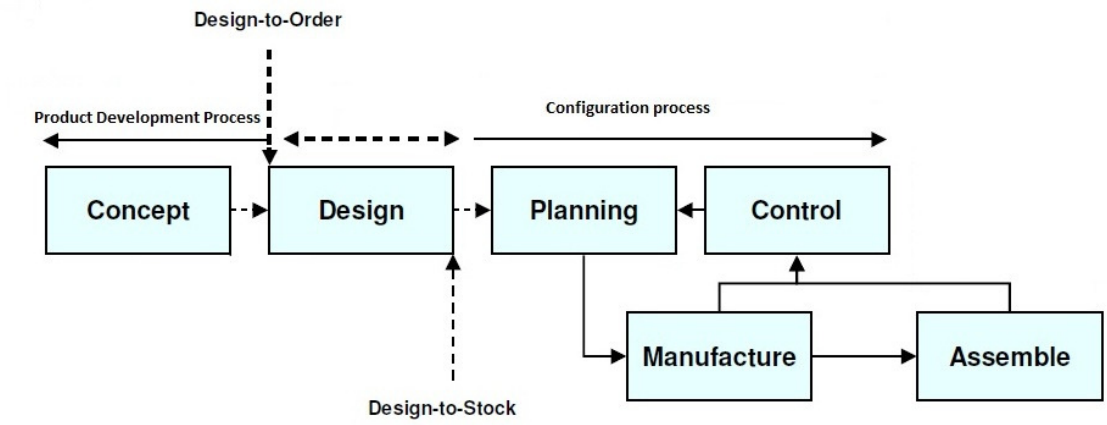

Figure 4.2. Production strategy when design-to-order and design-to-stock are used (from Kok, 2010)

One benefit with having concepts is that the projects no longer become one-of-a-kind projects. The design cost can be divided between many projects, which will make each project more profitable. The concept can also be optimised over time. Although, there is a need for more standardised components, the highly finished concept can only be used in certain places because of regulations from the municipals.

Winch (2003) considers that a make-to-order strategy, see Figure 4.3, is represented by building types where the required functionality does not differ significantly between locations, such as retail units, and schools or other certain standardised building types. These buildings may include those where branding is important across a chain, such as McDonald's restaurants, BP garages, and hotel chains. (Winch, 2003)

One could argue that the requirements and the required functionality for the end user of apartments cannot differ significantly between locations. The end user may have preferences, but for a small size apartment that is not that expensive, the apartment might not have to be perfect. So for smaller size apartments and houses a make-to-order concept might be useful, but it will probably be harder to sell larger apartments using a make-to-order strategy. Both Kuben and P303 follow a make-to-order strategy. The drawings that are already made are of a detailed design status and ready

to be used when the few options are decided. Therefore, almost all of the design work is already completed when using these concepts. (Edling, 22/05/13, Lindblad, 07/05/13) On the other hand, some design work still has to be performed, if the customer does want changes when using Kuben made from the original sketches as described above. (Edling, 22/05/13) Changes from the original sketches in P303 are very rarely made. For P303 the finished design work is ready to be used and except for the foundation no design work has to be carried out for each new project. As the whole design work is said to take about four hours for an individual project, the whole design phase is avoided. (Lindblad, 07/05/13)

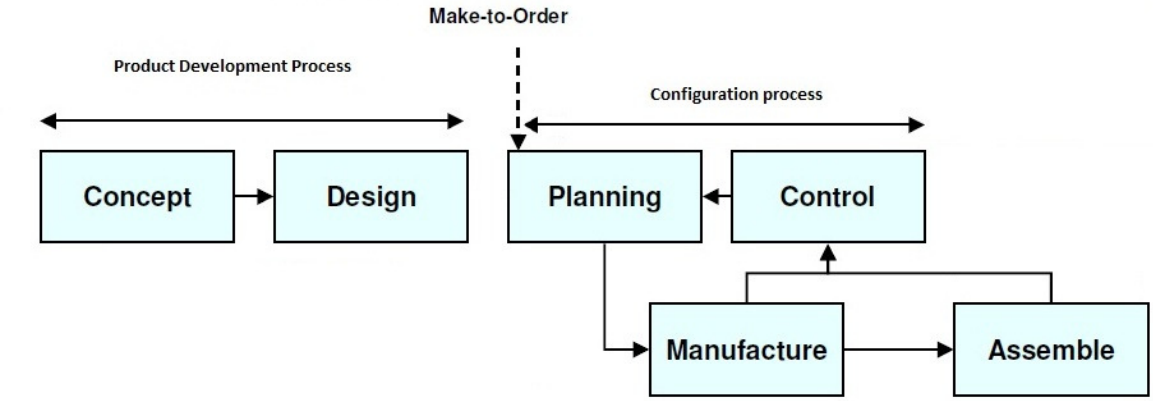

Figure 4.3. Description of the production strategy for make-to-order (from Kok 2007)

Furthermore, NCC Folkboende and sometimes P303 have separate divisions that focus only on the product development rather than the actual sale. This is something that is assumed to be necessary if a company wants to offer different kinds of production strategies. (Winch, 2003) These divisions can focus just on efficiency and do not have to pay attention to the individual sales. In contrast, the developers of Kuben are handling traditional projects as well and are therefore more flexibility orientated. For example, the interviewees concerning Kuben mentioned that a great benefit when having a concept is that even if the customer requested some small changes, NCC can still deliver the houses to less cost than otherwise. (Edling, 22/05/13) Therefore, the people dealing with Kuben are not as cautious about the concept, but are more oriented on selling. However, as Winch (1998) argues, the problem-solving mentality of building projects, as in a concept-to-order project, does not allow current problems to be evaluated as everything is project specific, that otherwise, the process is repeated and could more easily be improved with industralisation.

4.2 Insight into the building process with planning and control of the process

One of the important factors to achieve industrialisation is to have a well-defined process. This is harder to have when outsourcing activities to external consultants as they will perform their work in different way. (Lessing, 2006) These is something that Söderberg et al. (2010) also notices and continue that it is then important to have a very clear description of the building system, so it is possible to communicate the system to all actors, and thereby gaining experience and knowledge.

Lessing (2006) states that, to achieve a well-defined process, the planning and control system should be supported by advanced Information and Communication Technology tools and integrated with planning of supply chain activities. Performance measures give important input to planning, see Table 2.1.

Projects in P303 are said to be highly planned and controlled. As there are no changes, additional work or outgoing work allowed, the process will run more smoothly and some uncertainties are removed. (Lindberg, 07/05/13)

There is a detailed planning of all processes and a structured way of performing every step in the process in a NCC Folkboende project. However, this concept will get a lower score, because the people involved in the planning are not involved in the execution and therefore there is no guarantee that the planned process will be followed. (Karlsson, 13/05/13)

For Kuben there is a holistic structure of the project process, as the planning of the projects may differ depending on the situation on the workplace. (Edling, 22/05/13)

There is also a holistic structure of the process of the projects where the NCC Technical Platforms are used. In reality the process of these projects may differ due to the fact that the houses, the requirements for the projects or the situations that they are in may vary significantly between the projects. Hence, it will be harder to have the same control over all aspects of the projects. (Forseström, 20/05/13)

4.3 Developed technical system and innovations

When running in-house projects, NCC Housing should have more information earlier in the process from the evaluation of previous projects. Therefore, they should be able to take the decisions before they are needed. NCC Housing as a customer is more experienced to organise a project and therefore has better knowledge of the expected time schedule and costs. As it is predetermined which consultants will be appointed, the procurement process should take less time. Material can be standardised, as well as purchased earlier, and therefore logistics can be improved. Furthermore, NCC Housing could be the perfect example of the kind of customer who is an initiator of innovations in the construction process. They have the technical competence to understand what innovations are needed. Unfortunately, without major breakthrough, innovations cost money. It is therefore unlikely that NCC Housing will drive the necessary innovations, as their desire to achieve the most profit means that their projects have insufficient margins to support innovative thinking.

To get the highest score from Lessing's (2006) criterion on developed technical systems, the concepts should have a complex technical system, continuous development with other participants based on experience from projects and supported by Communication and Information Technology tools, see Table 2.2.

Only NCC Folkboende and Kuben meet this criterion. NCC Folkboende is based on a long term experience from projects and is continuously developed with other consultants, where some innovations are developed (Karlsson, 13/05/13). Kuben has a technical system, which is developed to meet new standards and therefore more complex than usually used in single family dwellings. However, the techniques used are not new innovations, as they are taken from former versions of the NCC Technical Platforms for multifamily dwellings (Edling, 22/05/13).

P303 lacks some elements of the Lessing's criterion, although there is a complex technical system designed for a quick process, but there is no development in partnership with the other participants. (Lindblad, 07/05/13)

As there are only certain building components in the NCC Technical Platforms, this concept will have an even lower score. However, these are based on a technical strategy that only these components should be used. This aspect might be improved later on after redesign of NCC Technical Platforms when all components are designed to fit to each other. When the consultants do not have to spend time on trivial things that can be standardised, they will have time to improve or work on the difficult solutions of the project that might not be included in the NCC Technical Platforms. NCC Housing should avoid having special solutions in their projects, if the NCC Technical Platforms are going to be successful. There are many improvements on the way to make the NCC Technical Platforms more usable, which is positive. The easier it is to use the NCC Technical Platforms in all stages, the more it will be used. This is demonstrated in previous versions, where the NCC Technical Platforms were harder to use, especially for external consultants, and were therefore not used to their full extent in projects.

4.4 On site or off site manufacturing

Another aspect said to be a problem within the building industry is that there is much onsite production. Academics like Koskela (2003) and Lessing (2006) argue that more prefabricated components are necessary to eliminate work performed at the building site to save time and to get a better and more consistent quality of the outcome. Prefabrication should eliminate uncertainties such as weather conditions and possible uneven work performance and this may lead to a higher degree of efficiency. (Koskela 2003)

There are too few suppliers due to the long tradition of onsite production and the costs for prefabricated components are supposedly higher than producing the house on site, something that all the interviewees pointed out. Furthermore, the market for prefabricated components is not sufficiently stable to be able to handle delivery times or business cycles, which therefore adds to the uncertainties. However, the interviewees wanted more prefabricated components to shorten the production time, if it was cheaper and reliable to use.

An important issue, when NCC Folkboende, Kuben and P303 were initiated, was that each design was supposed to be production friendly. Both NCC Folkboende and P303 have a structural system of onsite cast concrete. Kuben has a structural system of structural timber. The production is made in a way that has been applied for a long time in the company and therefore is well known. Karlsson (13/05/13) for NCC Folkboende, Edling (22/05/13) for Kuben and Lindblad (07/05/13) for P303 also argue that this way of production is also the supposedly cheapest way to produce their houses.

Lessing's (2006) criterion for a high score of offsite manufacturing of building parts are that advanced components are preassembled, design and manufacture are supported by Communication and Information Technology tools, advanced logistics principals and planning system, see Table 2.3.

There has been an example of a Kuben project having met this criterion where the whole house was manufactured offsite, because of the lack of storage space around the building site. However, for other projects, the whole house was produced on the building site. There are no set rules for the production, but it is preferred to produce it on-site as it is cheaper.

When producing a P303 multifamily dwelling the whole bathroom volumes come prefabricated to the work place for assembling, but the structural system is cast on site which gives P303 some lower score.

Both for NCC Folkboende and for projects where NCC Technical Platforms are used, subcomponents such as roof trusses and concrete elements are sometimes prefabricated. For projects where NCC Technical Platforms are used, even more advanced components are sometimes produced offsite, but this varies considerably between projects and therefore these concepts will get a low score.

4.5 Fragmented and temporary organisations or long term relations

There are often temporary organisations in the building industry. In addition, the industry is fragmented. Different occupancies involved in a project, which are not used to working together, now have to cooperate for a certain time period. Another problem with these kinds of temporary organisations is that the different disciplines might have limited experience of each other. With long term relationships between the participants, the consultants can learn from each other and develop a process that works. They can also get a better understanding of each other.

NCC is trying to make the company act like one entity instead of a company with a number of smaller separate divisions, in order to gain on economies of scale, high degree of repetition, small variation as well as coherence and coordination (NCC.se, 2013). Another benefit of working together is that NCC can establish routines and keep the knowledge within the company, which could lead to savings of money and time. By handling the process in this way, NCC is hoping that the process will be less fragmented. One example of this is that all divisions are involved in the development of new versions of the NCC Technical Platforms. NCC Housing strives to only use the structural engineers and building services engineers from NCC Engineering and all construction is undertaken by NCC Construction. For this to work fully, all required competences must be represented inside the company. Through this, the process and the products can be optimised and the divisions can learn from each other.

The benefit of working closely together to oppose fragmentation is that other companies will struggle to keep up. Working as one coordinated and comprehensive company and not a number of separate divisions working on the same project will create higher barriers of entry for other companies. If they are trying to tender for a project, both in-house and externally, as a single organisation that can perform all the design work as well as the production, others smaller companies will have it harder to compete.

When it comes to long term relationships, Lessing (2006) states that a company should have a structured program, which is used to work actively to develop relationships and cooperation. Evaluation is supported by Communication and

Information Technology tools. Strategic partnering is used comprehensively, see Table 2.4.

NCC Folkboende has driven this to almost the full extent. They have long term collaborations with all the important consultants. These consultants are also involved in the development of the concept of NCC Folkboende, as well as of each unique project. As the ground is project-specific and differs between each site, the NCC Folkboende Project Groups' approach to contract local organisations who know the area best may be appropriate.

Most of the consultants are contracted on a long term basis in Kuben. However, the only established long term partnership is with the architect, so the other consultants may be replaced in the future.

There are some long term relationships with key participants, but this is not considered as an important aspect of the group behind P303. On the other hand, the group that is working in all P303 projects since its initial establishment has also been working with the development of P303.

NCC Housing is working with NCC Engineering as much as possible for all kind of projects. However, one profession that NCC does not have in its organisation is designing architects and NCC must therefore collaborate with consultants. To have collaborations with four different architectural firms, like NCC Construction has, is good in the sense that they can get influences from different directions and do not risk to get stuck in a certain pattern. Another reason why this is positive is that the projects may differ much. In the meantime the architects can get to know NCC and the NCC Technical Platforms. It is important here that the architects can influence the development of the aesthetics related to the platforms, as this seems from the interviewees to be one of the most important aspects, if a project fits into the detailed development plan. On the contrary the benefits of collaborations fail when other architects are entering collaboration just for one specific project, for example the architect who has before worked with the detailed development plan. These architects do not have the knowledge of the platforms and the risk of designs that are not compatible with the platforms is therefore bigger.

4.6 Logistics integrated into the building process

Logistics should be one of the most important issues in the building process. Many uncertainties come from the building site. If this is in a city, there is often not much storage place and materials may also be damaged by exposure to the weather. Therefore production on site is seen as a necessary input resource. (Koskela, 2003)

To get the highest score when it comes to logistics integrated in the building process, Lessing (2006) states that supply chain activities should be fully integrated as natural parts of the building process, supported by Information and Communication Technology Tools for planning, purchasing, scheduling and design, see Table 2.5.

Only P303 has a defined process around the logistics of the construction site where just-in-time principles are applied to limit storage requirements. The development organisation of P303 is as well the only one that has control over the whole process. Another reason that the logistics are simpler for the workers in projects in P303 is that because there are no changes, additional work or outgoing work, there should not be any changes to the original sketched plan and therefore can the same logistics be used

for each new project. In addition, because there is only one person who takes care of the purchasing for all P303 projects, the project purchasing requirements are informed by his experience.

There are guiding documents when it comes to logistics for projects using the concept of NCC Folkboende, but there is no guarantee that they are followed, as it is a responsibility of the contracts manager for the specific project.

The logistics for the Kuben projects are intended to be that everything is bought just before production starts and then it comes to the building site with one week apart, but this might be changed due to the conditions on the specific building site. The whole house was delivered at once, when it was prefabricated.

The logistics for projects where the NCC Technical Platforms are used are not defined at all and are up to the site manager to decide as in traditional projects.

4.7 Customer focus in demand driven projects

The municipals often oppose a complete concept because it not always follows special requirements for the actual area. This seems to be a particular problem in the centre of cities. If a concept must satisfy the strictest requirements, it might not be cheaper to build than a tailored house and therefore loses one of its purposes.

It is though often said that value adding activities should be as flexible as possible and non-value adding activities should be highly standardised. One very important aspect to whether a concept can be used or not seems to be the aesthetics of the house. Many municipals have special demands for this which seems to be greater the closer to the centre of the town. This aspect might be easier for people dealing with Kuben to manage as areas with single family dwellings are usually situated outside the centre of a town. They have as well the most choices concerning aesthetics, so that the houses can be built in as many places as possible. On the other hand, NCC Folkboende is a point block and only needs a small piece of land. Therefore it could be built in a more central place, only if it complies with the aesthetic demands of the municipals. Therefore, it might be a good idea for the NCC Folkboende Project group to work on incorporating different facades or other aesthetic features into the concept.

One risk when having a concept is to add designs and change solutions depending on what the customer wants. For example, this has happened for Kuben. Until the market gets used to more finished concepts, might this be the way to act as it seems like the market is not ready for buying fully finished concepts yet. The iron triangle, cost, time and work, is still the most important and, even with changes to the concept, one will be able to give a price sooner than otherwise and the design work may still decrease compared to traditional projects.

Lessing's (2006) criterion for the highest score when it comes to customer focus states that the customer investigations and follow-ups are integrated with other activities, for instance, the technical development, production and assembly process and project planning. Information and Communication Technology Tools make the information transparent in the whole process, see Table 2.6.

At in-house projects where NCC Housing is acting as the customer and the Technical Platforms are being used, NCC Housing is supposed to know what the market wants, as the customer focus is high in such projects. These are demand driven projects where nearly everything is determined by the market, except for a few standards,

departure from which requires special justifications. However, the end customers have very limited choice in the project.

NCC Folkboende was established completely without the involvement of the market or the end user. Although most of the end customers' requirements and needs for NCC Folkboende are taken from experience, some solutions were tested on the market in Umeå before they were decided to be used.

Bookers and NCC Housing investigated what the market wanted when Kuben was established, but there is no systematic follow up of the market where a change is proposed. However, Kuben is continuously developed to meet requirements from customers for specific projects.

When P303 was established, market analysis were undertaken to determine what the market wanted, instead of what the customers wanted. There has been development in the concept due to customer feedback. In projects from P303, the end customers can rarely choose anything in the apartments.

4.8 Use of Information and Communication Technology

As Forseström (20/05/13) pointed out, with the usage of Information and Communication Technology tools, tasks can be made much more accurate.

Lessing (2006) states that companies should strive for use of advanced Information and Communication Technology tools by all participants to support other developed areas, for example, to support and integrate design, production, planning, performance measuring and purchasing, see Table 2.7.

There will be Information and Communication Technology tools to support all activities in the process in the future for NCC Folkboende. However, a strategy for Information and Communication Technology tools is used by the consultants today.

Information and Communication Technology tools are used for every part of the process in P303. This might be the only concept where the Information and Communication Technology tools is actually used all the way, as it is the same people handling the projects as developing the concept and, in some projects, even building the multifamily dwellings.

The level of usage of Information and Communication Technology tools in Kuben is the same as in NCC Folkboende and P303, where premade schedules, time plans and 3D models, as well as drawings are made. Detailed energy calculation of the worst case scenario is also premade.

For projects where the NCC Technical Platforms are used, it might be harder to use the same Information and Communication Technology tools, as the consultants are not always the same in every project. It is possible that, as the consultants physically work together one day a week in the project studio, they could get to learn about each other's Information and Communication Technology tools and find ways that fit for everyone in that project. However, this takes time and might not work until the end of a design process.

4.9 Performance measurements and reuse of experience

For performance measurement and reuse of experience Lessing (2006) gives the highest points for performance measurement of a number of aspects, experience collected and distributed systematically, and with Information and Communication Technology tools. This supports work with customer focus, relations, planning and industrial manufacturing, see Table 2.8.

The reuse of experience in P303 is supposed to be easy, as there are only a small number of people working with the concept. When they build the multifamily dwellings, they would know all the activities that go on in the project and can then share experience later on.

The performance measurement and reuse of experience is easy to manage as the group working with Kuben is still very small and all projects to date have been in the Gothenburg area. However, this will be harder to maintain as the concept grows.

The NCC Folkboende Project Group follows up each project and document the outcome. There is reuse of both design and technique whenever thought appropriate.

There are follow ups in some aspects and with the customer when the project is finished for all in-house projects. The documentation is handled only by an individual or a small group of people.

4.10 Comparison between the four different concepts

In this section are the scores for each aspect and concept presented, see Table 4.1 and the results are illustrated in the "Industrialised House-building Process Model" (the IHP model), represented by the wheel in Figure 2.2. From this wheel the overall industrialisation can be shown for the entire concept.

As can be seen from Table 4.1, the aspects with the lowest average overall score for all four concepts are given for offsite manufacturing of building components and logistics integrated into the building process. It is natural for NCC to continue with what they know well, since NCC has a long tradition of onsite production, especially in casted concrete. It is the cheapest way to produce, which then only adds to the reasons why they are performing this, as the concept should be profitable. Sometimes the process is more efficient and more reliable rather than the production. This is something that current studies about industrialisation are also more focused on. The market might need to find more innovative ways to produce cheaper and more reliable offsite manufactured building components to make it a more profitable solution.

Table 4.1 Results from the analysis concerning the eight aspects of industrialisation the four concepts using Lessing's (2006) criteria.

	Technical platforms	NCC Folkboende	Kuben	P303	Average
Planning and control of the process	1	3	1	4	**2.25**
Developed technical systems	2	4	4	3	**3.25**
Off-site manufacturing of building parts	1	1	0 (to 4)	3	**1.25**
Long term relations between participants	2	4	3	2	**2.75**
Logistics integrated in the building process	1	1	1	2	**1.25**
Customer focus	3	2	2	2	**2.25**
Use of information and communication technology	3	3	2	4	**3**
Systematic performance measurement and re-use of experience.	2	3	3	3	**2.75**
Average	**1.875**	**2.625**	**2**	**2.875**	

There is said to be a difference between industrialisation of the traditional building process and the concept industrialised building. This can be seen in the results from P303 and NCC Folkboende, where there is always the same team working with the product development process of the concept, which makes it easier for the team to stay focused on the actual concept.

The intention of NCC Folkboende was never to get an industrialised concept, but the concept reaches quite far out on the industrialisation wheel nevertheless, see Figure 4.4. Some scores are reduced because the team does not have control of the production or selling. The team has also focused on an efficient onsite production method using onsite cast concrete. On the other hand, the team can just focus on making the concept as strong as possible and does not have to focus on individual projects.

Figure 4.4. Degree of industrialisation for NCC Folkboende with regard to Lessing's criteria.

On the contrary P303 is said to be highly industrialised, which can also be seen in its industrialisation wheel, see Figure 4.5. The concept loses some points because the cost for onsite cast concrete is still considered cheaper than prefabrication and money is still a big incentive. Another reason for reducing points is that there are no contracted long term relations with consultants and that the customer does not have many options to choose from.

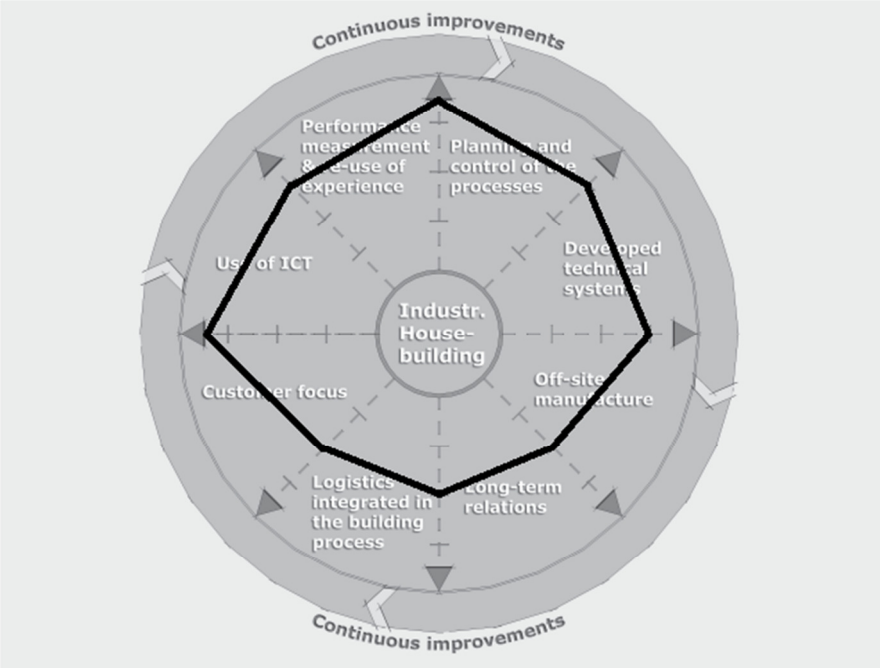

Figure 4.5. Degree of industrialisation for P303 with regard to Lessing's criteria.

However, the results of P303 and NCC Folboende demonstrate the importance of knowing what a concept should stand for when developing the concept and thereafter sticking to those ideas.

The opposite stands for Kuben where the people who work and develop the concept are working with other projects as well and the intention for Kuben was never to get a highly industrialised concept. This can be seen in Figure 4.6 where Kuben lacks several points on the industrialisation wheel. The only aspect that is at the highest is developed technical systems, because they had to develop new solutions in order to meet expected future regulation.

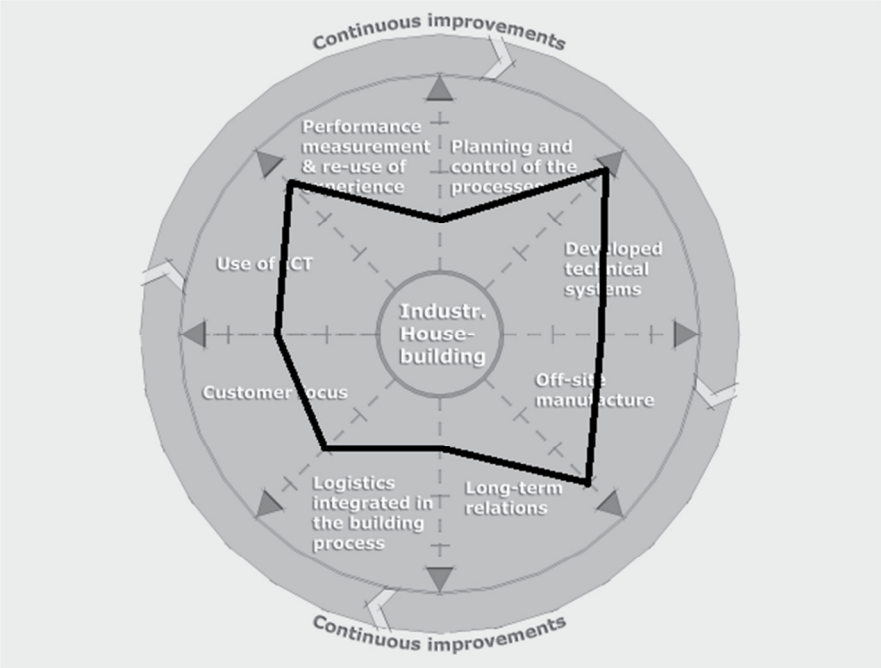

Figure 4.6. Degree of industrialisation for Kuben with regard to Lessing's criteria.

The concept NCC Technical Platforms has an average score around 2 on the industrialisation wheel, see Table 4.1. This is because the platforms are used in traditional projects and these are not very industrialised. The concept NCC Technical Platforms has a high score on customer focus, because the traditional building process is very flexible when it comes to meeting the markets needs and demands, see Figure 4.6.

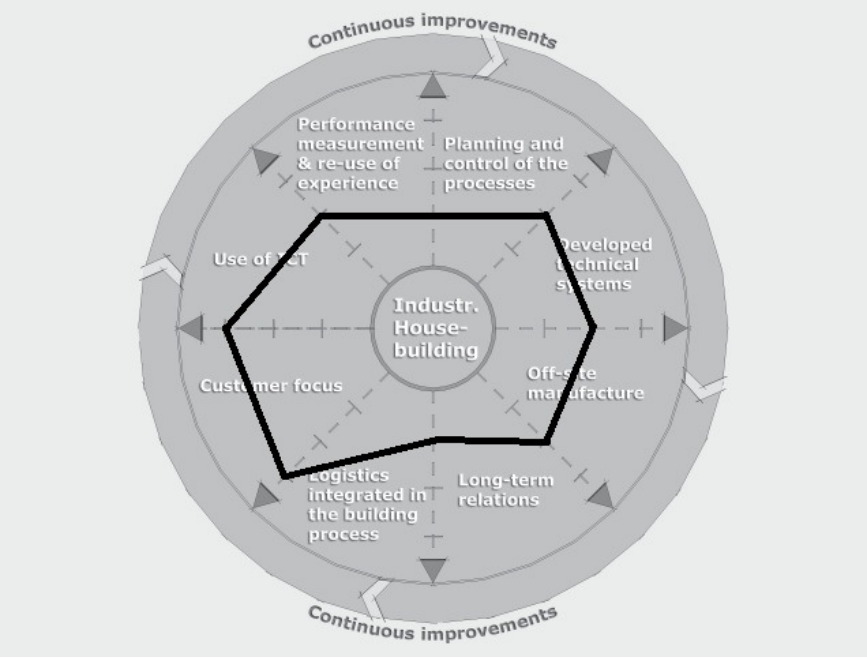

Figure 4.7. Degree of industrialisation for Technical platforms with regard to Lessing's criteria.

5 Discussion

Here are some thoughts about the outcome compared to the initial idea of the research. Then are some comments about the method procedure and the author's own objectivism and the reliability and validity of the results are discussed. (Bryman, 2002)

5.1 Discussion about the method

The original idea of this project was to look only at in-house projects because then NCC would have control over the whole value chain. This was not ultimately possible, because some of the concepts are so new that there have not been any in-house projects executed yet using these concepts. Therefore the concepts have been studied in not a specific project.

The results concerning P303, Kuben and NCC Folkboende, where no specific projects were investigated, only show the anticipated outcome. To get a more reliable result concerning these concepts, some executed projects should have been studied. However since all of the concepts had not been in-house projects, which is the only situation where NCC would have control over the whole value chain, the focus was on the anticipated outcome and then to get an idea of how in-house projects would be handled.

This influenced who were chosen for the interviews. To see what was project specific for in-house projects, the project manager or the design manager were intended to be interviewed as well as someone who knows the whole concept well. However this was only possible for the NCC Technical Platforms, where two in-house projects stood as examples for both the in-house process and the concept NCC Technical Platforms.

The interviews varied from being well structured to semi structured, depending on which direction the interview took. Some of the interviewees were more talkative than others and therefore discussion drifted into other areas that may not have been the main focus, but was something that the interviewees thought important. Some of these aspects were interesting to hear in the way that they gave a better understanding of the situation. Other interviews followed a more structured approach.

When evaluating the concepts with regard to Lessing's criteria according to Industrialised house-building (Lessing, 2006), concepts may satisfy some parts of the criterion but not with the entire definition. The score given is then what was thought to be closest, but this might have been different if another person undertook similar research. Some of the scores were also given to what is expected to be the outcome when some on-going development has been completed, but there is no guarantee that this will be the case.

Lessing's theory was formulated some years ago and may now be out of date. It is still one of the most known though. However the industrialisation today is, for example, much more focused on the process, rather than on the production. Therefore, perhaps companies should not strive to reach as far out on the wheel in all aspects. For example, the process used in the company might be faster or have more advantages than according to the theory that Lessing expresses. Lessing among others favours

offsite manufacturing, but this might not always be optimal due to the actual conditions in the industry.

5.2 Qualitative abductive research

Qualitative research is more a generation of theories rather than a testing of theories (Bryman, 2002). The qualitative research is often inductive (Bryman, 2002). An inductive research is when the author searches a theory from a general pattern in observations of the reality. It often includes some sort of uncertainty. Inductive research can be seen as a form of critical thinking where the research questions often are open-ended (Saleem, 2008).

On the contrary, in a deductive research the hypothesis or research questions will be stated based on a theory that already exists. Later there will be some sort of collection of data from which a result can be shown. This will then be discussed in order to establish if the hypothesis is true or false and then the theory might be revised. The last steps in a deductive research are of inductive nature where theory will be a result from observations, but the main part of the research is of deductive nature. The theory that will be studied can be as little as literature that exists in this field and the accumulated knowledge the author has gained from this literature. (Bryman, 2002) Deductive research is truth-conveying (Reichertz, 2010).

Abductive research is a mixture of inductive and deductive research. It is based on logical inference as well as profound insight. This kind of research is good when understanding of the situation is needed and, on the basis of data, reconstruction of new directives needs to be achieved. Abductive research cannot be used as an exact method in generation of logical ordered hypotheses but is a mode of reasoning to discover new knowledge. Abductive research answers the question of "what to do next". (Reichertz, 2010)

The method in this research study was a combination of all three research approaches, but biased towards the abductive research method. As the author's background is science orientated, she was used to deductive research. Three research questions were specified according to an abductive research according to theory (Reichertz, 2010). The questions were open-ended in an inductive way. The conclusion of the research came equally from theory and the interviews and would ``verify`` the questions as in induction. In the end, some sort of new theory was generated to provide recommendations for the case company.

5.3 The trustworthiness of the results

Because the situation in which this research is trying to picture is changing, the trustworthiness of the results will be harder to prove. Qualitative research will only give one of many possible ways to describe the situation.

5.3.1 External Validity (transferability)

In a quantitative research the external validity is referring to the fact that the research is supposed to be able to be generalised. This could be hard to do in a qualitative research, because a much more unique situation is studied with only a limited number

of subjects. In a qualitative research the results are supposed to be true in another context or at another time. To be able to give the reader the chance to see if this is true, Bryman (2002) utters that a detailed description of the situation has to be given. The generalisation is then supposed to be according to the theory and not according to the situation. (Bryman, 2002) In this thesis is the situation described in Chapter 2 and in Section 3.1.

5.3.2 Internal Validity (credibility)

Internal validity is a measure of the agreement between the theories that the researcher makes to the observations that are made (Bryman, 2002). It relies on the research design, data collection techniques, analysis of data and the results. To make sure that the researcher gives an accurate picture of the reality, it is necessary to enquire whether other researchers in this area as well as all the interviewees have been able to read the report before it went to print using a triangular motion. (Höök, 2008) Triangulation is used in case studies to eliminate inaccuracies in the research (Bryman, 2002). Two other researchers in this area as well as all the interviewees have been given the chance to read the report before it was finished.

5.3.3 Reliability (dependability)

A research has reliability if it can be repeated with the same result achieved. Because the interviewees are chosen for a specific project and the interviews are conducted in a semi-structured or structured way, the results may not be replicated exactly if the research is carried out again. The empirical evidence adapts over time according to the development made. Therefore it is impossible to repeat the research and still have the same results. (Bryman, 2002)

5.3.4 Values (conformability)

No author can be unbiased when doing research. The values of the author can be seen in everything from the choice of topic studied, the choice of how the collection of data is found to the analysis of the results and conclusions. It is then important to reflect over how the values can affect the research done. One criticism of qualitative research is that it is often based on the researchers own views of what is important. To make sure that this is not the case a wide range of articles have been studied, not just only on the subject but also on related subjects to get as broad understanding as possible. (Bryman, 2002)

6 Conclusions

The conclusions provided in this chapter are the outcome of this research. Then some recommendations to what NCC can keep develop are presented. Finally some suggestions to how this research can be continued are presented.

6.1 Conclusion of the four concepts

There has to be new and improved ways to shortening the time for projects in the building industry. Moreover, the costs and the quality for a building project have great potential to be improved. Increasing requirements and demands to be satisfied for each new project may lead to longer and longer time for planning and design. Furthermore, the extended usage of information and communication technology tools where the design can be made more extended and detailed can also contribute to increase design time. The building industry is a complex industry with several uncertainties and peculiarities.

Therefore, there is a need for some radical changes in the building industry. These changes will impact everyone from the municipal authorities to the contractor, consultants, suppliers and right down to the customers. The market has been using a concept-to-order strategy for so long that a more industrialised building process will need some fundamental changes of the industry. This change needs to start with governmental review and improvement of the process to develop and approve detailed development plans, so it does not take years for the construction of a building project to start.

Moreover, in the traditional building process there are five stages: concept, design, planning and control, manufacturing and assembly that are carried out for each project. In each project the building is seen as a new item with very limited reuse of solutions and experience gained from previous projects. For each project there are a lot of sketches that need to be drawn and the costing and time schedules needs to be updated several times during the process. There have to be geotechnical report, decided requirements over the environment, technical solutions and quality and geotechnical and site investigations which will end up in six different sets of drawings in the end, which have been more or less alternated during the process. This takes a lot of time.

This might not be necessary to do for each new project. There is everything from technical solutions to full set of building components that might be similar for each new house. However, in order for this to be better, there needs to be a higher tolerance for premade solutions and prefabrication in order to reduce the overall time for each new project. These changes for the entire industry will take time though.

On the other hand, everything listed above is still carried out in the industrialised building industry. However, some is carried out in a product development process where decisions are taken without customers and are standardised for each new project. The decisions that are not decided on in the product development process are decided by the customer in a configuration process. How much that is performed in the product development process can be described by different production strategies. The four concepts that were looked at followed different production strategies. NCC

Technical Platforms follow a concept-to-stock strategy, see Figure 6.1. This was the closest to traditional types of projects. These projects offer a great deal of flexibility.

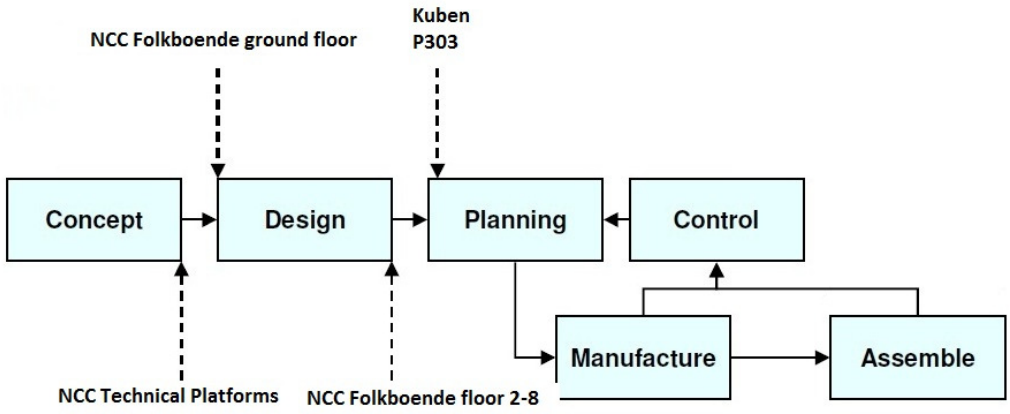

Figure 6.1. Sketch to see how much is done in the product development process (to the left of the arrow) and how much is performed in the configuration process (to the right of the arrow) for the four concepts

The other three concepts NCC Folkboende, Kuben and P303, that were studied at in this research project, are all well developed in the product development process and do not offer a great deal of flexibility. NCC Folkboende follows a design-to-stock strategy for all floors except for the first floor that follows a design-to-order strategy, see Figure 6.1. On the other hand Kuben and P303 are even more developed and both follow a make-to-order strategy. However, since the market is used to concept-to-order strategy, seems a design-to-stock strategy or a make-to-order strategy to be harder to introduce. The biggest benefit of these concepts seems to be the short time for execution and the low the cost.

One of the biggest advantages with a concept is the savings of cost. Development of concepts and technical solutions can be funded by a relatively small portion of the total project cost and a number of risks can be eliminated through design before major commitments of execution on site are made. Furthermore, the cost for the product development process can be shared across multiple projects and the more used a concept is, the lower the cost will be for each project. In this way projects do not become one-of-a-kind projects, which is one of the peculiarities of the building industry today. Furthermore, if the concepts are profitable they can be optimised to have developed technical systems that are at the forefront of innovations.

Additionally, many of the aspects that need to be changed are included in an industrialised building process. In this study, eight aspects of industrialising according to Lessing (2006) were used as a reference to define an industrialised building process. These are:

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

NCC has the opportunity to make many of the improvements that are needed when they have control over the whole value chain in an in-house project. NCC should first

focus on working with improvements that they have full control over, such as which consultants and suppliers to work with in long term relationships and to develop a process that serves everyone included in the projects. This might lead to increased costs during the transition time and must therefore be a decision taken high up in the company to make sure that decided solution is always followed for every project and not just followed when it is convenient or it does not cost more than alternative solutions.

One of the biggest obstacles for the well-developed concepts seems to be that they do not meet the aesthetics demands of the area where they are to be used. Only P303 and Kuben have alternatives for the façade and the roof, whereas these are already decided for NCC Folkboende. The aesthetics seem to have a major impact on whether a concept can be used or not, so it should be of great importance to have as many alternatives as possible, both some at a low cost, but maybe some more exclusive as well.

With more flexibility comes more uncertainty that will make the project harder to control. Therefore, having a well-defined process behind the projects is of great importance. However, it is important to always follow the prescribed process as much as possible and making sure that everyone knows it. Both P303 and NCC Folkboende have well-defined processes, so for NCC this is something that can be achieved.

There is a need for more prefabricated components, as prefabrication can eliminate many uncertainties, such as reducing the impact of weather and increasing the ability to control the quality of the components. However, currently the market for prefabricated components is not stable enough, so instead of reducing uncertainties with prefabrication, it may even increase uncertainties. This goes back to the long time it takes to execute a project, as well as the risk of economic fluctuations during this time period, which will add to the uncertainty.

Some of the problems in the building industry can be eliminated by choosing long term partners to work with. The collaboration will be better, which will lead to a smoother process. NCC should really take advantage of having competences within many disciplines in-house, which leads to increasing in-house capabilities as a result of closer collaborations. As in-house projects have differences between the projects, it is therefore favourable to have collaborations with different consultants, as long as these are the only consultants that NCC has collaborations with. Furthermore, there only needs to be collaboration with one consultant firm for the different disciplines when it comes to concepts, since there is only one concept.

When having concepts that follow a make-to-order or a design-to-order strategy, follow ups and being able to measure the performance are more important than ever. This is because the concept does not offer much flexibility, but must still deliver what the customers want and need.

As is seen in this research study, the incentive of a concept must not necessary be that it should be highly industrialised. It is more important, when developing a new concept to have a clear view of what the concept should stand for and what should be achieved by having this concept.

6.2 Recommendations

Concepts are good ways to shortening the design time. NCC should try to develop concepts that follow design-to-order strategy and focus on having as many architectural choices as possible. This will reduce time but still ensure that the concept is usable. The municipal authorities must not impose so strict directions in the future. Another big advantage for NCC is that, as they have tried a few concepts for some years, they can now learn from the benefits from the processes and then implement the most suitable solutions into the traditional projects.

NCC should focus on developing the process for production and make the onsite production the most efficient, as this is something that NCC has long experience of. There has to be a more stable market for prefabricated components for prefabrication to be a beneficial option and to make it a permanent part of the process. However, for those building components where there are stable suppliers of prefabricated components, these components should be used.

To shorten the production time and to improve the quality, NCC can work with improving the logistics on the building site, maybe by learning from P303 where a 'just-in-time' principle is used or to have logistic even further integrated into the building process.

Another aspect that NCC should work on is to have clear, well documented guidelines put into platforms. These should not only include the technical solutions, but also guidelines for the processes, the knowledge within the company, the relationship between different divisions at NCC as well as collaborations with other consultants and suppliers. Finally, NCC must make sure that everyone in the company complies with these.

6.3 Future research

This is a study concerning strategies and processes in a company which has the opportunity to control the whole value chain and has a few different value chains in-house. It might be interesting to investigate if industrialisation can be applied, and how, on suppliers or companies that produce parts of the value chain.

Another interesting question might be to investigate the viability of concepts using a design-to-stock or make-to-order strategy from a municipal authority's point of view or the possibility of collaboration between the municipal authorities and companies such as NCC to improve the usage of more developed concept.

This project has only been scratching on the surface concerning the eight aspects of industrialisation of how it is thought to be, but a study of how it actually is in real projects would be interesting.

One part of the process where these concepts at NCC do not seem to have clear guidelines is the logistics. Accordingly, another interesting study could be to investigate how logistics can be more integrated into the building process.

In current research in Sweden, the platform assets components, processes, knowledge and relationships evaluated in concept-to-order strategies, but this is also interesting in other strategies, as well as, to see the difference between different strategies according to the platforms.

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7.2 Oral references

Position	**Name**	**Concept**	**Date**	**Division**
Technical specialist	Anneli Pfeiffer	Technical Platforms	210513	NCC Engineering
Project manager	Hans Forseström	Technical Platforms	200513	NCC Housing
Concept manager	Sven-Erik Karlsson	NCC Folkboende	130513	NCC Construction
Business Manager	Per-Åke Edling	Kuben	220513	NCC Construction
Market and Business development manager	Henrik Lindblad	P303	070513	Byggsystem och produkter
Industrial PhD	Karin Gustavsson		280513	NCC Engineering

Appendix

Intervjuguide

Allmänt

- Namn?
- Befattning?
- Bakgrund?
- Kan du kortfattat beskriva ”konceptet”?
- Hur många projekt inom ”konceptet” har du varit med i?
- Kan du beskriva konceptet bakom ”konceptet”?
- Info om projekten
    - Antal lägenheter/småhus
    - Ungefärlig kontraktsumma
    - Kortare beskrivning, exempelvis läge, förutsättningar, omgivning
    - Vad brukar initierades ett ”konceptet” projektet?
    - Vilken arbetsform användes under projekteringen?
        - Projektstudio eller varligt?

What activities is a construction process made up of?

- När under projekteringen bestäms det vilket sorts projekt det ska bli?
  Vem bestämmer om det ska bli ett Folkboende eller Kuben osv?
- I vilken mån kan yttre faktorer påverkan projektet?
  Markförutsättningar osv. Skydd för dåligt väder, frost och tjäle?
  Finns det förutsättningar då ”konceptet” inte går att använda?
- Vad så som (se nedan) finns redan i forma av?
  Utformning arkitektoniskt
  Utredningar
  Ekonomi
  Tidsplan
  Miljöprogram
- Vilka yrkesgrupper är involverade?
  Interna/ Externa?
  Varför valdes just dessa?
  Har de varit med i tidigare projekt?
  Upphandlingsform

Design

- Hur långt är ritningarna färdiga från början?
  Finns förslagshandlingar, huvudhandlingar el bygghandlingar för alla yrkesgrupper (A, M, K, V, E)
  Används ICT verktyg för dessa?
- Vilka yrkesgrupper är involverade i förslaghadlingsskedet, huvudhandlingaskedet, bygghandlingaskedet?
  Interna/ Externa?

Varför valdes just dessa?
Har de varit med i tidigare projekt?
Upphandlingsform

- Under de olika byggskedena, vad kan projektörerna ändra på?
  Kunden?
  Han som ska bo där?
- Hur stor skulle du säga betydelsen av projekteringen i ”konceptet” är?
  I jämförelse med produktutvecklingsprocessen?
- Hur stor skulle du säga omfattningen av projekteringen i ”konceptet” är?
  I jämförelse med produktutvecklingsprocessen?
- Blir någon av projekteringsskedena viktigare – mindre viktig?
  Försvinner någon?
  Ändras ordningen?
  Tillkommer någon?
  Förändrad betydelse/omfattning?

Inköp

- När under byggprocessen köps materialet in?
  Görs några inköp redan under projekteringen?
  Om ja, i så fall vilka?
- Finns det standardavtal när det gäller inköp?
  Vad skulle göra att standardavtalen frångås?
- Vem är ansvarig för inköpen?
  Är detta samma person i alla ”konceptet” projekt?
- Hur fungerar logistiken på byggplatsen?
  Kommer materialet när det behövs?

Byggstart

- Hur mycket av ”konceptet” förtillverkade eller platstillverkade?
- Hr lång tid ska ett ”konceptet” projekt normalt ta?

What strategic choices could be made from the differences in activities?

- Finns det platser där projektet inte är möjligt att bygga med standard utföranden?
- Vem upprättade/projektspecifierade projekteringskraven för ”konceptet”?
  Vilka yrkesgrupper var inkluderade i denna process?
  Är detta en pågående projekt?
  Hur mycket involverades marknaden i denna process?
- Vad kan utvecklas för att ”konceptet” ska bli ännu mera attraktiv i framtiden tycker du?
- Kan du beskriva de arkitektoniska friheter som finns med ”konceptet”?
- Hur fungerar erfarenhetsåterföringen i ”konceptet”?
- Med de förbestämda ritningarna som finns, vilka möjligheter finns det för ändringar till andra situationer?
- Om varit med i tidigare projekt för ”konceptet”, vad har ändrats sedan dessa?
  Vet du varför det ändrades?

Vad tycker du om ändringarna?

- Vad är det bästa samt vad skulle kunna förbättras med ”konceptet” tycker du?