CHALMERS
UNIVERSITY OF TECHNOLOGY

Collaboration between Design and Construction

Addressing the Challenges of Bridging the Knowledge Gap

Master's thesis in the Design and Construction Project Management Programme

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CHALMERS UNIVERSITY OF TECHNOLOGY
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Master's Thesis: BOMX02-16-59

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Preface

This master's thesis is the is the final step in Mikael's master's degree in DCPM (Design and Construction Project Management) and Tommy's Civil engineering degree with the same focus. The thesis work took place in the spring of 2016 at a large Swedish construction company in Gothenburg, Sweden. It is a case study examining the collaboration and transfer of knowledge and information between design and construction, focusing on three managerial roles whom are involved in this transfer.

In this preface we also want to take the time to thank our examiner Christine Räisänen as well as our supervisor at Chalmers and the studied company: Janni Tjell M.Sc. PhD. for her insights, discussions, encouragement, time, and honesty, without which this thesis would not have been completed.

We would also like to thank the studied company and its employees for their acceptance of our presence and participation in interviews and queries. Without you, there would have been no report to present at all.

Thirdly we would also like to thank Sharoz Sahba, Business manager at NCC, for inspiring and discussing areas of research prior to this thesis.

Mikael Johansson Tommy Silversten

Göteborg, 2016

As you think, so shall you become.

- Bruce Lee

Acronyms

AEC	–	Architecture, engineering and construction
BIM	–	Building information model
DSM	–	Design structure matrix
ICE	–	Integrated concurrent engineering
ILPD	–	Integrated Lean Project Delivery
IPD	–	Integrated Project Delivery
JIT	–	Just in time
LPD	–	Lean Project Delivery
LPS	–	Last Planner System
MEP	–	Mechanical, electrical, and plumbing
NPD	–	New product development
PPC	–	Percentage planned complete
TDV	–	Target, Value, Design
TFV	–	Transformation, Flow, Value
TPS	–	Toyota production system
VDC	–	Virtual Design and Construction

Translations

Design manager – Projekteringsledare

Project manager – Projektchef

Site manager – Platschef

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ABSTRACT

In the current construction process, many issues encountered during the production phase of a project can be traced to quality issues in design development. This study aims to analyze the current processes for transferring knowledge and information during the handover of a project from the design phase to the production phase in a large Swedish construction company. This, in order to identify how the current knowledge- and information sharing processes affect the project. At the studied company, the majority of the knowledge and information exchange is conducted through three managers; the Design manager in charge of the design phase, the Project manager that has the overall responsibility of the project, and the Site manager in charge of the production phase. The current process, in the design phase, tries to increase collaboration and exchange of knowledge and information through co-location of the consultants. The research was conducted as an inductive, qualitative, case study with three cases, where the three roles mentioned above were interviewed in each case. Lean philosophy is used in this study as the basis for identifying tools and processes that provide solutions for transferring knowledge and information.

The study shows that there is a need for increasing the collaboration and communication between the three roles in order to decrease the boundaries between the two phases. This in order to diminish the amount of issues transferred from the design phase to the production phase. It is identified that there are three main areas that affect the project process negatively. (1) The different interpretations of the different roles, regarding their responsibilities and obligations leads to misunderstandings and differences in prioritization during the project. (2) An unwillingness to attend or collaborate through design meetings decreases the possibility for transferring knowledge and information. (3) Knowledge and information regarding issues encountered in the production phase is lost before the post-production review meeting.

Key words: Lean Construction, Lean Design, Project Based, Integrated Project Delivery, Boundary Spanners, Integrated Design, Knowledge -Sharing -Transfer, Communication

Sammarbetet mellan Projektering och Produktion
Utmaningar med att Överbygga Kunskapsklyftan

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SAMMANFATTNING

I den rådande byggprocessen kan en stor andel av fel som hittas i byggfasen av ett projekt spåras till kvalitetsbrister i utvecklingen av projektet i projekteringsfasen. Denna studie ämnar analysera den nuvarande kunskaps- och informationsutbytesprocessen mellan projekterings- och byggfasen hos ett av de största entreprenörsföretagen i Sverige. Detta för att identifiera hur de nuvarande processerna påverkat projektet i helhet. Hos det studerade företaget sker majoriteten av kunskaps- och informationsutbytet via tre ledare; Projekteringsledaren som bär ansvaret för projekteringsfasen, Projektchefen som har det yttersta ansvaret för projektet i sin helhet samt Platschefen som bär ansvaret för byggfasen. Företaget försöker att förbättre samarbetet i projekteringen genom att samlokalisera konsulter i denna fas. Studien utfördes som en induktiv, kvalitativ fallstudie med tre fall där de tre rollerna som nämns ovan intervjuades för varje fall. Lean-filosofin används som bas föra att identifiera verktyg och processes som skulle kunna förbättre överföringen av kunskap och information.

Studien visar att det finns ett behov av att öka samarbetet och kommunikationen mellan de tre rollerna, detta för att kunna minska de barriärer som finns mellan projekterings- och byggfasen. Detta ökade sammarbete leder i sin tur till att minska de brister från projekteringsfasen som når byggfasen. I denna studie identifieras tre områden som har en negativ påverkan på projektprocessen: (1) Skillnader i tolkningen utav rollernas ansvar och skyldigheter leder till missförstånd och varierande prioritering i projekten. (2) Bristande vilja att delta och, eller delta i projekteringsmöten minskar möjligheterna för att överföra kunskap och information. (3) Kunskap och information gällande brister funna under byggfasen förloras innan kunskapsåterföringsmötet vid slutet av ett projekt.

Nyckelord: Lean Konstruktion, Lean Design, Projekt Baserad, Integrated Project Delivery, Boundary Spanners, Integrerade Design Möten, Kunskaps -Delande -Överföring, Kommunikation

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1. Introduction and Background

The Swedish construction industry is accused of stagnant productivity development. However, due to the uniqueness and complexity of the construction industry, coupled with an increase in quality for both the product and the production process, efficiency and productivity of the construction industry is difficult to evaluate. (Byggkommissionen, 2002; Statskontoret, 2009; Lind and Landin, 2011). Even though it is difficult to evaluate, many researchers agree that there is a low increase in the efficiency and productivity in the construction industry when compared to other industries (Lind and Landin. 2011). In order to improve, several focal points are discussed, such as; change pressure from the client, environmental factors, education as well as research within the industry (Statskontoret, 2009).

Josephson and Saukkoriipi (2005) show that flaws and problems occurring in the production phase are approximately 30-35% of the total construction cost. Of these, it is claimed by the reviewed literature that a large portion of problems can be linked to quality issues that can be prohibited in the design phase (Byggkommissionen, 2002; Statskontoret, 2009; Lind and Landin, 2011). Josephson (1994) identified that 51% of all problems can be attributed to quality issues in the design phase. Dealing with these issues in the design phase, stops these problems from spreading to the construction phase. Solving the problems in the design phase will thereby increase the quality of the construction documents in terms of what the production team can, and is able to build.

The aim of this report is to explore how information and knowledge is shared between design and production. In order to address this question, case studies have been conducted in one of the largest construction companies in Sweden. In the studied cases the design and construction phases are primarily managed by three managers; the Design manager, the Project manager, and the Site manager. The collaboration and communication between these managers influences the construction process in terms of how knowledge and information is shared between the design and production as well as how design receiving feedback from the production phase. Therefor it is interesting to acquire a greater understanding of how and why information and knowledge is shared. Between these three roles barriers for knowledge and information sharing stem from the fact that people act, work, focus, and understand or interpret situations differently (Carlile, 2002), and once a culture for working in a certain pattern or solving problems in a certain way is established, changing these cultures and habits becomes more difficult.

The current process used in the company for the design phase is a Design Meeting System developed by the company. This method uses elements from the Lean philosophy to direct the projects focus, and increase collaboration between the parties involved. The Lean philosophy's contribution to this phase is to lead the project team towards providing the best value for the customer. To create a Lean process that fulfills the goal of creating the best value for the client, the project is dependent on a high degree of knowledge exchange between the phases. Enabling that the right knowledge is available in the right place, at the right time, or in other words; just in time (JIT) is desirable for creating the best value. JIT aims to make the project processes as streamlined and efficient as possible by making all the knowledge and information necessary for the development of a project available when the knowledge is needed. JIT is described further in chapter 3.3. To facilitate that the knowledge and information is available at the right time, the three managers mentioned above have the utmost responsibility for this exchange. The studied area is visualized in figure 1.1 on the following page. This figure shows the mangers' described involvement in the different phases of the project process as well as the imagined gap between the phases that is the focus of this study.

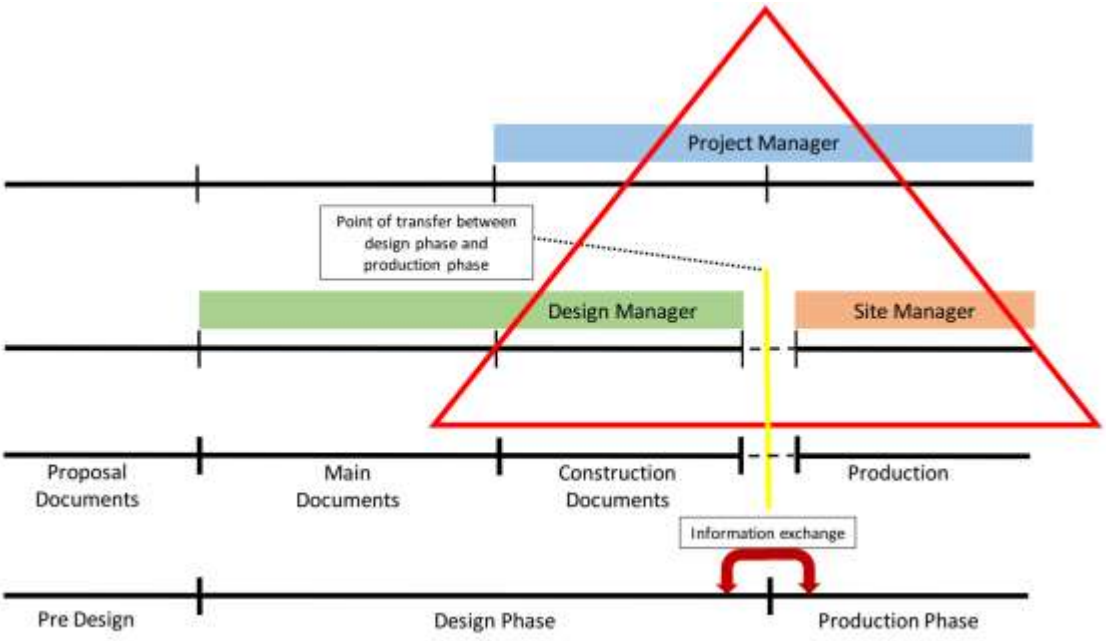

Figure 1.1: Visualization of the project process and the area of research.

1.2 Aim and Research Questions

The aim of this research is to investigate how knowledge and information is shared between design and production. Secondly, the research aims to explore how members within the phases collaborate in order to exchange knowledge and information.

Research questions

RQ1: How is knowledge and information shared between design and production?

Upon viewing the process of the investigated company, we have observed that specifically three roles impact the transfer of knowledge and information between design and production. This spawned the second research question.

RQ2: How does the collaboration between these roles affect the project?

1.3 Delimitations

The research is limited to a time frame of approximately six months, in compliance with the required time frame for master's thesis work at Chalmers University of Technology. This restriction contributed to the choice of width of the research. The research is limited to the knowledge and information transfer between the design phase and the production phase in domestic housing projects, and does not consider the design phase or production phase in itself. Lean will be the second focal point for the literature study, used to identify tools and processes for solving issues regarding the transfer of knowledge and information. Within each phase the report focuses on the tools and models

related to the aim of the research, and does not emphasize other tools used within these phases, e.g. VDC within the design phase.

The scope of this research is to examine the three managerial roles: Design manager, Project manager and Site manager with regards to how they share knowledge and information during the phase shift between design and production. The study is conducted through interviewing the three individual roles in a total of three cases. However, the research does not consider the foremen or consultants roles in regards to their effect on the handover.

1.4 Disposition

The report is divided into three parts; (1) Theory formation, (2) Empirical data collection through findings, and (3) discussion and conclusion. The overall disposition for the report, identifying connections between the three parts is presented below and in figure 1.2.

2. Method: This chapter describes the methods used during this study. The methods used for literary review and empirical data collection are described. The chapter describes the case study method used as well as validation for and choices of, cases and interviewees. Lastly, a discussion concerning limitations and challenges of the methods is conducted.

3. Theoretical Framework: Contains the theoretical framework this study is based upon. The aim of the chapter is to (1) create an understanding for the main concepts of the reviewed areas for the reader, (2) to show the width of the authors research, and (3) to back up and reinforce the findings and discussion chapters.

4. Case Study: Describes the cases studied in this research, and the current project process used in the studied company.

5. Interview Findings: Portrays the findings of the interview study in relation to the research questions and aim of the study.

6. Discussion: Relates the interview findings to the theoretical framework in order to identify possible correlations within the researched area.

7. Conclusion: Uses the theoretical framework, interview findings, and discussion to arrive at conclusions regarding the research questions or the study. The authors also suggest solutions for the issues identified and suggestions for further research.

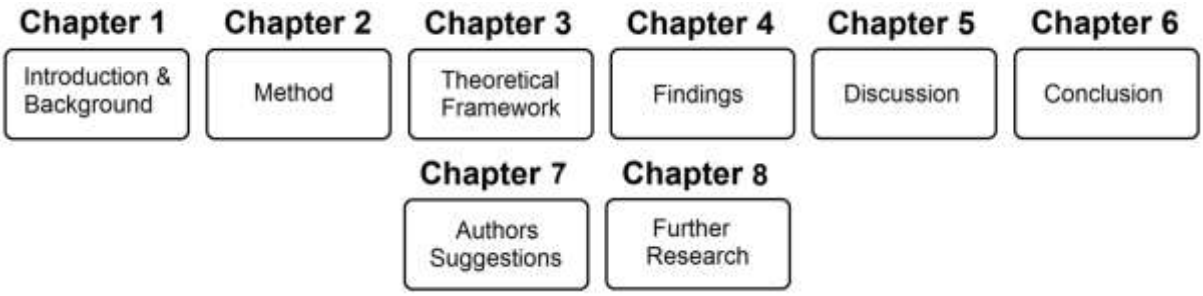

Figure 1.2: Disposition of report.

2. Method

This chapter describes the methods used during this study. The methods used for literary review and empirical data collection are described. The chapter describes the case study method used as well as validation for and choices of, cases and interviewees. Lastly, a discussion concerning limitations and challenges of the methods is conducted.

Within scientific research there are two main methods, qualitative and quantitative. Qualitative research focuses on the interpretation, relation, and analysis of text. This information is gathered through literary reviews, as well as vocal or written communication with respondents affiliated with the area of research (Bryman, 2011). This is the method chosen for this research due to the primary data collected being interviews. According to Bryman (2011) qualitative research is primarily used to understand and analyze a situation based on the participants described views and experiences of it. Because the qualitative method is adapted for identifying correlations and links in and between information, it is well fitted for answering the chosen subject and research questions.

According to Bryman (2011), a main critique of the qualitative method is its interpretability, and that it is often defined as 'non-quantitative'. However, since the study is interpretative, with a high focus on the interviewees' descriptions of participation, and close relation to a specific environment the qualitative method allows the researchers to examine the non-quantifiable aspects of the process. A qualitative approach also allows the researchers to analyze the interviewees perception of the process, supporting the choice of a qualitative method.

The data collected is analyzed according to an inductive reasoning which means that the study is conducted in an area where a problem is found. The researcher uses the study to identify patterns and draw conclusions, where after theory is reviewed to find a theoretical explanation to support the observed conclusions (Patel and Davidsson, 2011). This method was chosen because of the direct ability to link collected data to the theory researched. The inductive approach also has the advantage of allowing the researcher to extrapolate conclusions based on observations.

Research Design

The research is split into three stages specified below:

(1) A literature review based on scientific research papers, studies and books within the identified fields. The literature review main goal is to increase the understanding of Lean Construction, Lean Design, transferring knowledge in project organizations, and boundary spanners. The literature review is used as a base for formulating the framework and questions for the interviews in the case study.

(2) The case studies are based on internal documents regarding the specific process of the cases, and indirect experienced, through a series of interviews with interviewees within the cases. Choice of interviewees is mainly based on their direct link to the researched field. The case study portrays the current processes used in the cases, as well as identifying the interviewee's opinion and view of these processes, highlighting weaknesses and strengths of the cases. The choice to use three cases is based on the fact that it will create a matrix of comparison (Figure 2.1), where each case can be compared to two other cases. This comparison limits the risk of the study only showing a specific relationship between two cases, resulting in more reliable empirical evidence.

(3) Thirdly, the literature review and the case studies are linked. This is done in three levels:

1. Analysis of the cases and roles individually.
2. Comparing the cases in a matrix.

3. Analysis of the correlations between the case study data and the literature review.

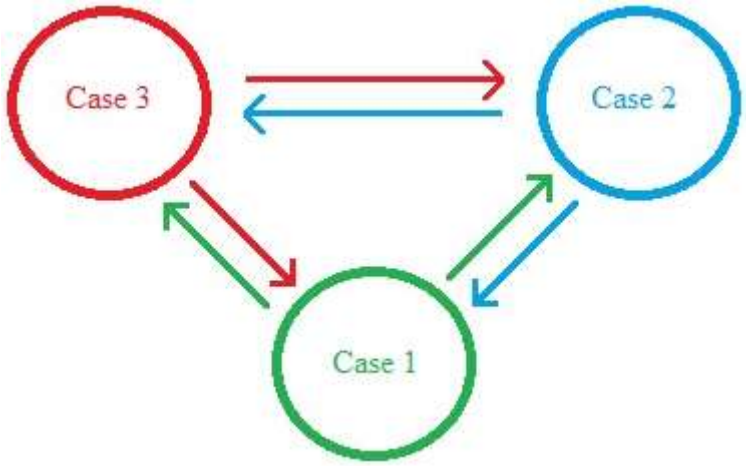

Figure 2.1: Visual representation of comparison-matrix of cases

The following sub-chapters (2.1-2.3) present a more in depth description of the three main parts of the report described in short above. After these methods are presented, the criteria and selection for both cases and interviewees are described, along with a validation of the method chosen for the study as a whole.

2.1 Literature Review

A literature review was carried out in order to gather information about the investigated area of research to create a theoretical background. This was done prior to the formulation of interview questions to be able to have a better informational exchange in the interactions with the interviewees.

To search for information, the used databases were: Chalmers University Library search tool: Summon, and Google Scholar.

Key word used in the search were: Lean Construction, Lean Design, Project Based, Integrated Project Delivery, Boundary Spanners, Integrated Design, Knowledge -Sharing -Transfer, Communication

When only using the key words when searching for relevant information, there are thousands of hits, most often 1,000-20,000. When combining the different key words the hit-numbers decreased radically. Also, adding the word 'construction' to the key words (or the combinations of key words) was used to limit the number of hits. In addition to this, looking at the number of citations for the different articles helped identify prominent researchers such as; L. Koskela; G. Ballard; A. Dainty; P. Carlile, etc. In the literature review, there are several authors of great importance for their field, used frequently and as a foundation for latter work and research.

In addition to the key words and author citation, the literatures applicability was determined through reading abstracts and conclusions before eliminating or accepting the use of it in the literature review.

Field	Authors
Lean	J.K. Liker, L. Koskela, G. Ballard, A. Khanzode
Knowledge Transfer	P. Carlile, E. Wenger and I. Nonaka
Team Leaders and Boundary Spanning	S. Brion, A. Dainty, S. Newell

2.2 Case Study Method

A case study is an investigation into a certain project or special set of circumstances, that Yin (2009, p. 4) claims *"Allows the investigator to retain the holistic and meaningful characteristics... of organizational and managerial processes"*. Yin (2009) categorizes the case study method according to three criteria.

1. Its research questions aim to answer 'how' and 'why' question.
2. The researchers do not have control of the researched cases' or interviewees' behavioral events.
3. The researchers are concerned with current events.

If a study does not fulfill all these criteria, other methods, such as experiment or surveys that are concerned with more quantifiable data might be more suitable. However, this study contains all three mentioned criteria, and is therefore a prime candidate to this kind of study.

The application of the case studies, are many, however the most important, according to Yin (2009) is to *"...explain the presumed causal links in real-life interventions that are too complex for the survey or experimental strategies."* (p. 19). To find these links he has divided the method into five stages (Yin, 2009).

1. Design
2. Prepare
3. Collect Data
4. Analyzing and Discussing Data
5. Reporting Findings

In this chapter, the five steps are briefly described, focusing on the choices and activities performed in these steps during the research. A more detailed description of the five case study stages is found in appendix 5.

Design: The study consists of three case studies, this in order to achieve a less vulnerable result, from an analytical standpoint. *"if you can do a two-case case study, your chances of doing a good case study will be better than using a single-case design."* (pp. 60-61). The number of cases chosen for this study was limited by the time-span of the study, where the assessment of the available time and resources resulted in the selection of 3 cases, which resulted in a total of 10 interviews with 8 interviewees whom all are employed at the company studied and has one of the three roles studied.

The reliability in the design of this study is dealt with by choosing methods reliant on proven methods, thereby mitigating the researcher's biases when interviewing subjects and analyzing the cases chosen for this study. This chapter portrays the choices and methods with which the authors conducted this study. This could be used in order to replicate the results, or duplicate the study with altered variables.

Prepare: In preparation for the case study data collection, four steps were taken, supported by Yin (2009).

1. Researching interview methods.
2. A protocol containing the topics to be discussed in the interviews was developed (appendix 4). This protocol was used during the interviews to help steer the conversation.
3. Interview questions for the topics defined in the protocol were formulated (Appendix 4).
4. Introductory interviews were held with two managers within the case studies. This was done in order to (1) identify additional cases, (2) find suitable interviewees for the study, (3) gather information about identified issue, as well as affirm that this issue exists within the company.

Collect data: Data collection for this study was conducted in two parts; interviews and secondary data. *Secondary data* collection was conducted through gathering internal documentation describing the cases and processes used within these.

The data collected through *interviews* was split into two stages; introductory and main interviews. The introductory interviews were held with DM1 and DM2 in order to, as mentioned above, validate the focus of the studied field. However, the interviews were also used in order to further insight into the cases' current process and background. Primary interviews were held with all 8 selected interviewees in the 3 cases from March 14th – April 8th 2016. To save time and create a flow in the discussion with the interviewee, all interviews were recorded, after approval from the interviewee. This allowed the interviewers to focus on the interviewees answers, to come up with better follow-up questions instead of writing most of the conversation down. Interviews were approximately 40 minutes. Interviews with SM1, -2, -3 as well as PM3 interviews were held on the construction site of the case studied. Remaining interviews were held at the company's head office in Gothenburg, Sweden.

Conducting interviews allows the interviewers to gain information of the studied cases, and the views of the interviewees (Yin, 2009). In this study the semi-structured interview method is used to conduct interviews. The open interview format allows for the interviewee to respond to questions from their point of view, often giving a broad picture of the studied cases (Bryman, 2011; Yin, 2009). The questions for the interviews focus on level 1 and 2 questions of the 5 levels of questions identified by Yin (2009) (Appendix 5). These questions were used during the interviews in order to focus the interviewees' answers to views and observations for the individual case and not their experience when relating to prior work. However, some questions developed were aimed towards identifying the interviewee's opinion on 'how things should be'. This was done to gather additional information regarding solutions suggested by the interviewees.

To mitigate the risk of misinterpretations and misunderstandings during the interviews the content of the interviews were sent to the interviewees at the end of the study for validation. A additional limitation for this study with regards to interviews is; the interview held with PM3 and SM3 was held in the presence of each other, perhaps limiting the answers of the interviewees. However, the tone of the interview was relaxed, and the interviewers did not detect any tension between the interviewees during the meeting. The responses to the summations sent out should also reveal if the data obtained in this interview is conflicting with the interviewees' opinion.

Analyzing and Discussing Data: Analysis for the collected data was performed through a combination of Explanation building and Cross-case synthesis in order to find; causality, patterns, and draw conclusions (Yin, 2009). The interviews were summarized and distinctive or correlating quotes written down. The summaries were then analyzed in reference to (1) specific cases, (2) specific roles,

and (3) between cases as a group. This analysis revealed correlations between the roles, and cases (Chapter 4: Findings) and was used to compare the findings to the theoretical framework (Chapter 3).

Reporting Findings: This final stage might be the most important. If the findings are not understood by, at least, the identified target group, the entire study has been a waste. This is dealt with by organizing the structure of the report in such a way, as to lead the reader through the theories used and cases investigated, in order for the reader to be intrigued and understand conclusions. This structure-method is described by Yin (2009) as 'theory-building structure', and is well fitted to exploratory case studies like this one. As the theory-building structure suggest, each chapter in this report therefore reveals new information, adding to prior chapters, thereby building the readers knowledge through the report to increase understanding of the research area and ultimately, the conclusions reached.

2.2.1 Case Research Design Summary

The case study *Design* is a three-case study based on interviews. When established which roles within the project teams were of interest the number of cases was chosen in order to be able to complete the interviews and research needed within the time frame. When the overall design of the case study was established, the researchers *Prepare*d for the data collection by reading interview methodologies, developing an interview protocol and interview questions. Lastly, two primary interviews were held in order to confirm the research aim and case selection. The developed interview protocol and questions were then used in the interviews to *collect data* for the case study. The data collected was then summarized and data analyzed through explanation building and cross-case synthesis. Finally, the *findings are reported* (Chapter 4) through describing the case research in relation to the topics of the report.

2.3 Case Selection

Cases for the study were selected in order to cohere with the research questions identified for this study. The cases were also selected based on a desire to study projects with similar preconditions. These preconditions formulated the criteria for the basis of which the cases were selected.

1. Domestic housing project
2. Design phase performed in the Design meeting system (Chapter 4.1.3)
3. Ongoing or concluded design phase.
4. Geographically located in Gothenburg and surrounding urban areas in Sweden
5. Same preconditions for involvement of site personnel in construction documents.

Projects are further described in chapter 4.1: Case Study.

2.4 Interviewee Selection

To investigate the research questions within the field of study, three key roles involved were identified. These are the Design manager, Project manager, and Site manager identified in the table below. The choice of focusing on these three specific roles was due to: (1) the limited time frame of the project, (2) the comparability of cases, and (3) their relation to the research area.

Table 2.1: Interviewees names, roles, projects and codename hereafter used in report.

Project	Project Manager	Design Manager	Site Manager	Code
Case 1			X	SM1
Case 1		X		DM1
Case 1/Case 2	X			PM1/PM2
Case 2			X	SM2
Case 2		X		DM2
Case 3		X		DM3
Case 3			X	SM3
Case 3	X			PM3

2.5 Analysis and discussion

The last stage of analysis is, as described in chapter 2, "analysis of the correlations between the case study data and the literature review" (p. 5). The method used for this analysis is a combination of pattern matching and explanation building (Yin, 2009). The pattern matching is used to find correlations between the findings from the case study and the theories and models identified in the theoretical framework. This was an iterative process, where the authors questioned the correlations within the findings and between the findings and the theoretical research to find logical correlations. This analysis used explanation building to narratively justify the correlations through a discussion (Chapter 5).

2.6 Method and Validation Summary

The method of choice: Qualitative Inductive Case study

The qualitative method allows the author to use data collected through interviews within the three cases, which is the primary method of data collection in this study. The qualitative method has, by Bryman (2011), been critiqued for having a lower replicability as well as reliability compared to a quantitative approach. The authors have because of this, allocated additional effort to the description of the process, why and what choices were taken to progress this study.

The multi-case study model allows for the authors to compare a wider range of projects, with the possibility to choose cases that have similar preconditions in order to better discern correlations between findings and theoretical framework, by comparing several cases. It also allows for the authors to interview several interviewees that have the same role, identifying similarities in their views of the project process. However, the chosen method limits the research, by opting out a deeper investigation with a broader interviewee-range available in a single case. Ideally, the on-site foremen for the studied cases would also have been interviewed, in order to determine the overall view of the studied questions.

3. Theoretical Framework

This chapter describes the theoretical takeoff for this MSc thesis. In the first section the theoretical lens will be described in terms of addressing how knowledge is transferred. The second section is a description of the theory used to identify suggestions for addressing the issue of knowledge sharing. For this MSc thesis the Lean philosophy was chosen. Therefor the second section is a description of the concept of Lean construction starting with a historical introduction and a description of the Lean philosophy.

3.1 Knowledge and Learning in project organizations

This chapter describes the theories of knowledge creation and distribution within project based organizations used in this thesis, focusing on the barriers within these. First, a section on knowledge creation and sharing is presented to increase understanding of the barriers. Following this section the barriers and boundary spanning activities within projects are described.

3.1.1 Knowledge Creation and Sharing

To transfer knowledge and information between two parties or more, the information or knowledge needs to be codified or conveyed in a manner where the other parties are able to: receive, process, and make use of this information.

Knowledge exists in two variations: (1) Knowledge that one gains through questioning ones cognitive relations, referred to as Possessional knowledge (Ackoff, 1989; Newell, 2009) or Explicit (Nonaka 1994). (2) Knowledge that one obtains by experiencing or performing a task, referred to as Practice-based knowledge (Ackoff, 1989; Newell, 2009) or Tacit (Nonaka, 1994). However, Newell (2009) also states that tacit knowledge is a social or group encounter, where; sharing stories, descriptions and techniques are a vital part of the knowledge creation. According to Newell (2009) this is particularly true in diverse groups such as construction engineers, where the social setting can enhance or diminish the knowledge created greatly. To clarify the knowledge creation and sharing in groups through combining, sharing and receiving tacit and explicit knowledge, Nonaka (1994) uses the model seen in figure 3.1 to specify the settings where the sharing of tacit or explicit knowledge occurs to the highest extent.

Figure 3.1: SECI Model: Knowledge conversion ("place" of knowledge transfer, added in this study)

As portrayed by Nonaka's (1994) model in figure 3.1, the conversions pertaining to tacit knowledge, are most efficient during human interaction through face to face meetings or through project work. This is reinforced by Dainty et.al. (2006) highlighting the importance of choice of communication channels, Dainty et.al. describes the 'face-to-face' and 'project team' channels as two-way communication, which has advantage over one-way communication through it allowing for reciprocation.

3.2 Knowledge Sharing- and Communication Barriers

The following chapter is dedicated to identification of barriers for knowledge sharing and communication. This chapter focuses on barriers created by: 'Trust', 'Culture', 'Knowledge', and 'Learning', followed by a section describing the theories for bridging these barriers.

3.2.1 Trust

For communication to be transferred between two parties efficiently, the issues of trust influence the communication. Trust in that the information transferred is accurate and that the counterparty is committed to the same goal. According to Newell (2009), to achieve efficient knowledge sharing in the project group, a high-trust relationship is required. It aids collaboration and commitment to the project from all parties involved. Newell continues by discussing three identified types of trust:

Companion trust: The trust that is built on a continuous, mutual personal relationships or social network, built on honesty and reliability. Loss of trust causes larger ramifications.

Competence trust: Reassurance that trustee will, and is able to, conduct a task within their area of expertise in a agreed-upon fashion. Trust built on reputation, or other physical evidence of the trustee. Loss of trust will not have any larger ramifications, however loss of trust occurs quickly if task is performed incorrectly.

Commitment trust: An agreement or contract proving the parties' commitment to the project. Trust built on an understanding that all parties have something to gain from the project. Trust stronger than competence trust, due to contract, but weaker than companion trust, since it is not built on a long-term relationship.

3.2.2 Culture

Cultural differences, referring to societal and organizational culture, as defined by Merriam Webster's Dictionary (2015) as a predisposition to have a belief, custom, behavior, or way of thinking, that is brought on by residing in a specific environment. Dainty et.al. (2006) discusses barriers of effective communication brought forth in literature.

- Underestimating the influence of cultural differences is one of the largest barriers. Understanding that cultural diversity, language and interpretations, as discussed below, differ between cultures.
- Understanding and expectations differ between cultures. Understanding and interpretation, on an individual level is shaped by the environment. Expectations of interactions differ with nationalities, organizations and communities.

- Selective adherence or cognitive dissonance. A disregard of, or challenging response towards information that does not adhere to the receivers' culture or perceptions, creating gaps in the information flow.
- Language: the use of different languages and dialects challenges communication flow and reception.
- Jargon: a set of words or references that are used in a certain environment or context, where the intended meaning of the jargon is hard to understand, or has a different meaning, for someone from a different community or culture, leading to a miscommunication.
- Stereotyping is the act of viewing someone through a socially/culturally constructed framework, where communication may be misunderstood or misinterpreted because the sender or receiver has segregated the other party into a certain community. This is also applicable to gender differences, where assumed gender roles are stereotyped, as well as the "halo or horns"-effect, where a person is disproportionally agreed or disagreed with depending on the traits of the trustee (Law, 2009), this is however generally based on first impressions.

These seven barriers are identified as having entirely or partly cultural aspects affecting the communication within and between organizations and project groups. Holistically, the organizations way to interact with others is done through the organizational culture. Differences or misinterpretations between cultures may result in a high frequency of disputes and, due to this, a project process that is of lower quality.

3.2.3 Knowledge Barrier

The Knowledge barrier is the barrier of variation in knowledge possessed between different parties in a project (Figure 3.2 below). This is relevant in a multidisciplinary project structure which includes several parties that need to possess and understand knowledge in the same way. E.g. within the design and production phases of a construction project. This barrier is visualized through figure 3.2 below. A differing knowledge between project members can strain the relationship to a higher degree than needed. In order to identify and traverse these boundaries, Carlile's (2002) categorizes the knowledge barriers into three different categories: *Pragmatic*, which means that one interprets a situation based on one's background and has difficulty combining this interpretation with others interpretations. *Syntactic*, which is the difference between one's way of communication in comparison so someone else. Or, *semantic* which is a difference in interpretation of communication based on background. These categories highlight boundaries of understanding communication between parties.

Syntactic boundaries are the differences between one's way of communicating in comparison so someone else. I.e. ways of encoding information for it to be understood by the receiver, e.g. using a certain program or language where there are differences in communication of a common topic or context.

Semantic boundaries are boundaries where one knows that there are syntactic differences, however, the understanding, interpretation, and views of the common event or situation, differs between the parties. These boundaries highlight the difficulties in expressing knowledge and information, and have it understood in the intended way by the receivers. It also suggests that for any given situation, there can and will be differing interpretations of the situation.

Pragmatic boundaries are connected to a difference in interest between parties e.g. uneven use of knowledge, or a difference in use of programs or tools, both depth of knowledge and practices used

(Bosch-Sijtsema, 2013). The parties tend to show a predisposition towards the status quo and are inflexible and reluctant towards adopting new processes/information because 'they' already know what to do, and how to do it (Clegg et.al., 2011; Dainty et.al., 2006) A well known example of this is Kodak barely avoiding bankruptcy because they kept focusing on traditional film-cameras instead of digital.

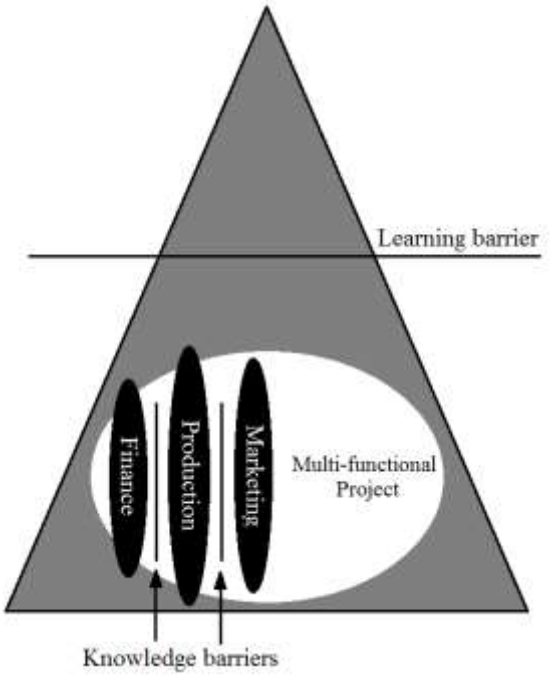

Figure 3.2: Learning and knowledge barriers (Newell et.al., 2009)

3.2.4 Bridging the Barriers

To aid sharing between organizations and parties, management of; organizational-, knowledge-, and learning- boundaries, is necessary (Clegg, et.al., 2011; Koch and Thuesen, 2013; Karrbom, 2013). Wenger (1998, p. 290) states that boundaries are *"...at once unavoidable, necessary, and useful..."* saying that they can be used as an advantage, bridged where necessary, and at times eradicated. When managing boundaries between organizations, Clegg et.al. (2011) promotes three methods used: Brokers, Objects and Interaction. This thesis focuses on the knowledge transfer between two or more entities and will therefore focus on Brokers.

Brokers. Identified as persons that act as a link between two or more parties creating and sharing knowledge i.e. tacit and explicit knowledge exchange through; coordination, mediation, socialization (Nonaka and Takeuchi, 1996; Wenger, 1998). According to Karrbom (2013) brokers span geographical-, professional-, and stakeholder boundaries, making brokering a very useful tool in communication facilitation. Ancona and Caldwell (1992) also identified the aforementioned boundary-spanning activities, however also including "scouting" and gathering new information as well as "Guarding" activities from being released before finished. Koch and Thuesen (2013) do however express a concern of the vulnerability of networks, linked with brokers, in case of loss of a

broker and their tacit knowledge of the project. Long et.al. (2013) add to this by stating that the stress put on brokers by the magnitude of the task can exacerbate the broker if not supported correctly.

3.2.5 Boundary Spanners

The mangers for the different phases in the construction industry are the team leaders for their team. Dainty et.al (2006) claim that within the construction industry the managers roles are the most demanding, where the collaboration and communication within and between several parties is a large part of their day.

The Project leaders have a position where they are the filters of information and communication towards the project group as well as being the face of the project outwards, putting them in an exposed position from the perspective of overcoming the boundaries. They are the brokers of the project (as described in chapter 3.2.4). Haas (2015) states that it is important that the brokers are aware of the importance of their role, and the influence exerted by them, as well as what types of activities should and can be prioritized in order to achieve the required result. The project leaders will also obtain knowledge between projects, making them very important for cross-project learning.

Haas (2015) describes Boundary spanners as *"interfaces between a unit and its environment who can play several different functions, including information exchange and access to markets and resources"* (p. 1030). This fits well into a description of a project leader who will be seen as the face of the project as well as having access to informational channels to stakeholders. Brion et.al. (2012) identify four boundary spanning activities performed by the project leader, which are correlated with project performance in NPD-projects (New product development). (Similar to the activities described in the paragraph 'Brokers' in chapter 3.2.4)

1. Political Support: Understanding the political surroundings to determine the expectations from the project and aligning this with the company's strategy and goals.
2. Team Protection: Selecting what informational channels that reach the entire project group based on what is necessary for the project success.
3. External Coordination: Communicating with external parties and key stakeholders e.g. feedback on progress and process
4. Information Scanning: Searching for and forwarding knowledge and information regarding new processes and technical information to the project group.

Brion et.al. (2012) also claim that within multidisciplinary projects, the activities described above are important parts of the project leaders' duties, in order to steer the project group towards the common goal and keep from taking faulty or uninformed decisions. Their study shows that Political support and Information scanning are the most important with regards to a successful project outcome.

3.3 The Lean Philosophy

To give insight into where Lean came from in order to understand the Lean way, this chapter presents the Lean philosophy concepts.

The notion of Lean came to be after WWII when Toyota, undergoing financial struggles, went looking for a more efficient system of operations. The leading producer, praised for their fast production, was Ford and their moving assembly line (Krafcik, 1988). However, Toyota was concerned by the high stockholding levels of the Ford system and developed a modified system called the Toyota Production System or TPS. TPS is, as described by Liker (2009), the 'DNA' of Toyota; It

is a management principle and philosophy system, however, it is also a way of life. A system that should be in every person and every aspect of the company's development.

TPS is described as a house on two legs, as seen in figure 3.3 the 'TPS house': Just In Time (JIT) and Jidoka (quality aspects). JIT is a method of receiving orders, tasks or information exactly when needed in the development if the project or product. As shown in the figure below, the part that arrives to the production needs to arrive at the correct station when the work flow allows for installation of the part. The product needs to be of the correct sort, quality, and quantity. In addition to this, the worker assembling the product needs to have the right tools to install the part and have the correct knowledge and tools to assess if the part that has arrived fits all the criteria correctly. At any time in this process, the worker also needs to be able to signal if any of these criteria are not met, so that production can be stopped and the process corrected. This report will focus on JIT as it is applicable to information and knowledge exchange. The JIT method relies on a 'pull' in the system. This means that the information required needs to be requested to the point of need. (Liker, 2009; Womack et.al., 1990; Krafcik, 1988). In the described scenario above, this means that the worker signals that s/he has found a problem in the process. Together with the process design team, the worker expresses the problem, and develops a solution. Implementation of the solution results is a more efficient system that is able to create a better value for the customer. Essentially TPS increases the value for the customer by becoming more efficient and more flexible.

Figure 3.3: The TPS-House (Liker, 2009)

The aim of Lean philosophy is to produce the best value for the client. Liker (2009) describes the Lean philosophy through the 4P model (Figure 3.4). This model could help other industries apply the Lean philosophy. The 4P model shows how a Lean system is created through the application of 'Philosophy', 'Process', 'People & Partners', and 'Problem solving' to the organization.

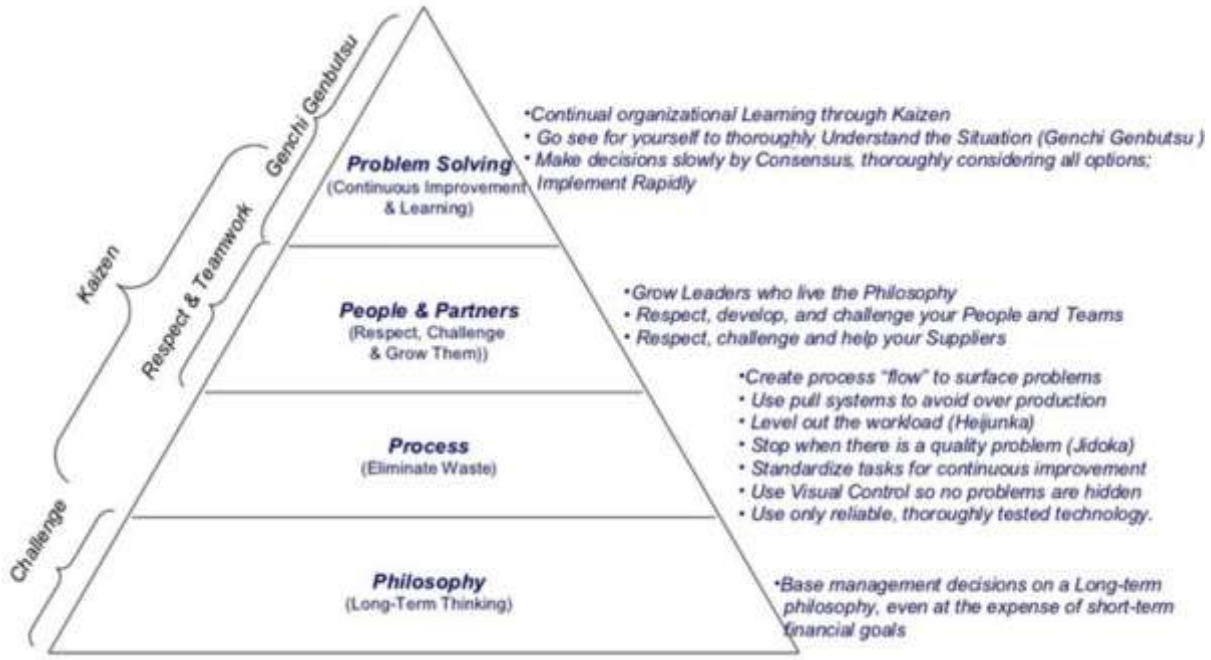

Figure 3.4: The 4P-model (Liker, 2009)

The first step in Liker's (2009) model is to base the system on the Lean (1) *Philosophy*, a way of thinking, living, and behaving that affects all conditions and decisions in the strive towards the ultimate goal of producing value for the customer. The second step is to use (2) *Process*es that enable this philosophy. To facilitate creating the best value for the client processes are standardized, have short lead times, are easy to check and continuously improved upon. An example of this is the backflow of information as a standardized form or signal that shows management that there is a problem or improvement possibility in the process. The third step is to work with (3) *People and Partners* who also strive towards excellence. This is conducted through high collaboration and respect for coworkers, suppliers and customers, as well as educating leaders and coworkers who are one with the philosophy. The fourth and last 'P' in the model ties together the three others. The (4) *Problem solving* is used to continuously improve the processes within the system through a constant reflection over processes. However, this problem solving is reliant on that the philosophy has established a culture where change towards the betterment of the process is a ongoing process. It is also reliant upon that the people within the processes have taken the philosophy to heart, in order to be able to take advantage of the workforces' knowledge in developing new processes, as well as creating a culture where the workforce feels like they are listened to. Allowing this is necessary in order to create a problem solving team that enables the use of the Lean philosophy towards creating the best value for the client.

The resulting system is 'the Lean way' (Liker, 2009). The Lean way takes a philosophy of creating value for the customer, through the process of JIT and continuous improvement, with the right people and partners, who want to grow and be challenged, in order to create a learning organization that can solve any problem. This creates a culture of employees that are thinking and solving and adding value to any process within the company.

3.4 Lean Construction

The four 'P's' described above are necessary in order to do things the 'Lean way'. However, the research in this report focuses on the application of this method to a project. A project is characterized by being time limited, unique and highly dynamic (Maylor, 2010). Ballard and Howell (2005) show in figure 3.5 below that the more dynamic a project is the higher the focus is on relational contracts. These contracts are contingent upon collaboration and communication, furthering the need for problem solving and evolving people and partners who are a large part of the 4P model Liker (2009) uses to describe Lean and TPS. Lean is therefore suggested to be used to manage the chaos of a highly dynamic project that is also highly relational, i.e. a construction project (Ballard and Howell, 2005).

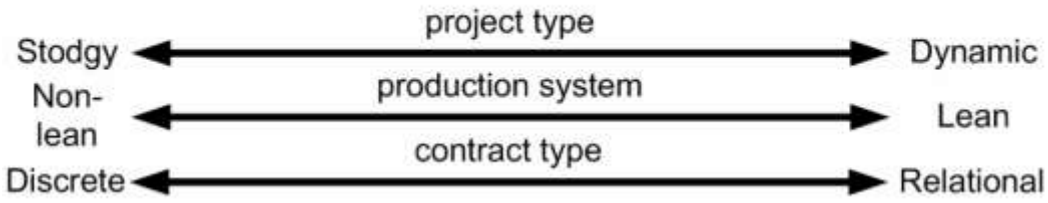

Figure 3.5: The spectrum of contracts correlated with types of production systems and projects (Ballard & Howell. 2005)

3.4.1 Lean Construction History

Lean construction is about creating the best client-value by focusing on value adding activities and reduction of non-value adding activities, similar to the Lean production philosophy described in chapter 3.3. The notion of Lean construction was however first described by Lauri Koskela in a CIFE report: Application of the New Production Philosophy to Construction in 1992. In this report, Koskela introduces a holistic mindset to examine the construction process as well as the projects delivered. According to Koskela et.al. (2002) success in a project lies in finding the balance-point in a triad containing the three aspects of Lean visible in figure 3.6 (TFV). The Transformation and Value aspects of this triad are also in the traditional construction process method. However, Flow is added by the Lean philosophy. The Flow, refers to all activities, works, and preconditions that need to be attained in order to complete a task. This is further described below.

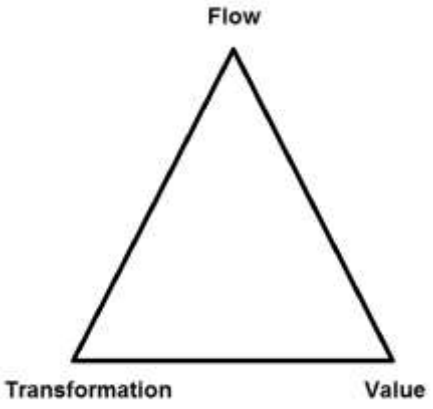

Figure 3.6: Transformation-, Flow-, Value- triad

Figure 3.3: Transformation-, Flow-, Value- triad

Transformation – A holistic view of change from idea to finished building through tasks. The act of creating output from input. This can be any activity or partial activity that is scheduled to be performed, from the production of elements in a model, to the arrival of concrete to a work site.

Flow – As mentioned previously, the added focus of Flow is what sets the Lean philosophy apart from other theories. The Flow refers to the gathering of all that is needed for a task to occur. E.g. in order to make design decisions, all the knowledge and information needed has to be present. Koskela (1999) defined seven flows that affect the task to be performed (Figure 3.7). These Flows that in this case is the flow of knowledge and information between the design phase and the production phase, needs to be monitored and scheduled in order for the task to be completed on time, to the customer defined value. To create the best value, the flows need to complement and coexist with one another. The design solutions need to have; the right consultants with the right knowledge in the right place at the right time in order to produce the right design solution with the right value. These flows are reliant on that the process design is organized in a JIT manor (Koskela, 1999), otherwise; the construction designs might not match what the workers can build, the materials needed are not of the right quality, quantity, or in the right space. In the context of this research, the flow of knowledge and information to the design phase needs to correlate with what the design team needs in order for the Flow of construction documents to match what can be built on the construction site. If this or any other flow is off point, the flow needs to be altered in order to increase the accuracy of the process towards creating the best value for the client.

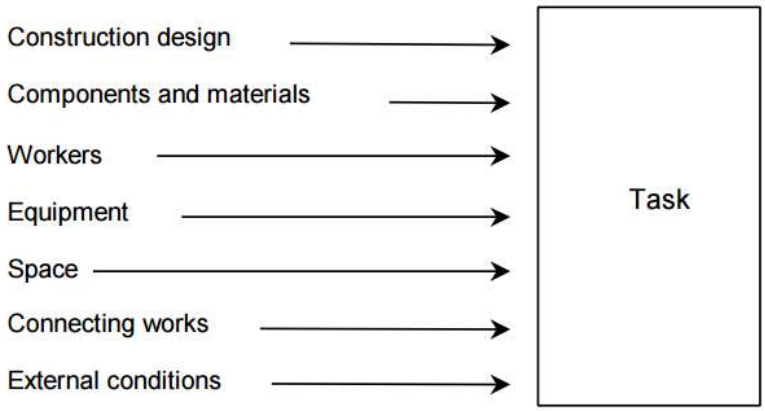

Figure 3.7: The seven flows to a construction task. (Koskela, 1999)

Value generation – Identifying the value adding processes in terms of quality and requirements from the client, and focusing on these and not any other non-value adding activities.

The goal of Lean construction is to, through the aforementioned aspects of TFV meet customer demands, improve the quality of the product and methods used, as well as becoming a learning organization that increases efficiency by problem solving through continuous improvement (Koskela, 1992).

3.4.2 Lean Project Delivery System (LPDS)

LPDS is the use of Lean philosophy adapted to a construction project setting. This system is an attempt to create more efficient way to design and produce within the construction industry.

LPDS uses the TFV triad and explained in the previous chapter to balance the flow and focus towards customer needs in the transformation. It also attempt to facilitate the flow of information, knowledge and tasks between the phases of the construction process. As seen in figure 3.8, the model visualizes the collaboration between the phases through the overlap of the triads representing the construction phases. Finally, the model emphasizes the need for a backflow of information and feedback.

According to Koskela et.al. (2002) and Ballard (2000) LPDS has many benefits over the traditional project delivery. LPDS strives for a holistic, transparent view in the process, involving stakeholders and decision makers from each process level in the earlier levels contributing to the backflow of information. This is visible in figure 3.8, which depicts the five phases, as represented by the five triads, of the construction project, how they overlap and depend on one another. The traditional process, as opposed to LPDS, focuses on transactions and contracts, and where decision-making as well as the different levels of the process are performed in a consecutive order. A popular metaphor used to describe the traditional method is a series of phase-areas separated by walls. Decisions are made and work is performed in the first phase of the process after which this is "thrown over the wall" to the next phase, where new decisions are made and work is performed where after this is thrown over the wall, until the project is completed. This without a defined collaboration between the levels, leads to disagreements and problems between, and in later phases. This is what the LPDS system aims to amend.

In order to define the LPDS Ballard (2000) defined the following seven key characteristics or techniques that are essential for the use of LPDS. These characteristics are important for all phases of the project, especially the transition between the phases where there is a larger risk for informational loss through loss of involved members in the project group.

1. Structure and manage the project as a series of processes adding value to the project by fulfilling quality and client requirements.
2. Involve stakeholders and decision makers from subsequent phases on the project in the planning and design phases.
3. Use of Lean project control: methodical organization of the tasks to be performed (Koskela et.al., 2002)
4. Take measures to ensure that the work flow is calculable and reliable rather than focusing on productivity improvements.
5. Establish pull in the material and information flows.
6. Use buffers to compensate for variability in the project.
7. Feedback between phases as well as post occupancy evaluation is used. This allows for adjustments in the earliest stage possible, as well as contributing to organizational learning.

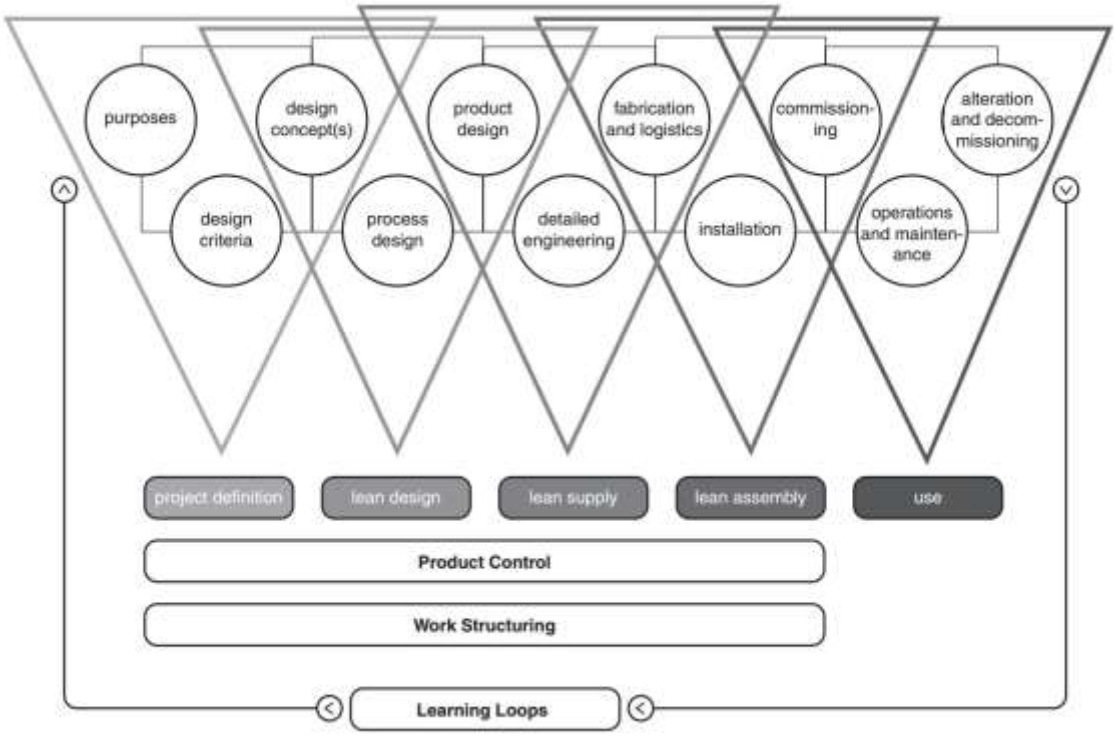

Figure 3.8: Visualization of Lean Project Delivery System (Koskela et.al., 2002).

The use of LPDS allows, as mentioned above, for the involvement of a larger group of stakeholders in the early stages of the project, as well as facilitation of continuous improvement through the constant feedback between the phases. However, Bertelsen and Koskela (2002) stress that it is crucial for the TFV mindset to be implemented throughout the entire construction process in order to fully take advantage of the benefits of LPDS. This report studies the handover between the 'lean design' and 'lean assembly' phases of figure 3.8. Therefore the Lean design process will be further investigated below.

3.5 Lean Design

LPDS aims to create a flow through the construction process. To investigate the phase shift between design and assembly, this chapter depicts the workings and methods used through the design in LPDS in order to understand how these affect the handover described in the research questions.

Lean design is the phase where the design team continues from project definition, as seen in figure 3.8, in order to define the processes and final design of the project, focusing on collaboration and planning (Munthe-Kaas, 2015). Several methods are used to facilitate this phase of the project. The literature focuses on collaboration, co-location and creating a 'Pull' in the system, in order to aid knowledge and information sharing (Ballard, 2000; Kent and Becerik-Gerber, 2010; Nguyen, 2010; Liker, 2009; Khanzode, 2014). Therefor the primary aspects which are considered relevant for this study have been identified as:

- Push/pull
- Collaboration
- Co-location

3.5.1 Push/Pull

A goal in Lean is to create a 'pull' in the system. This means that there has to be a need expressed by the client or by downstream phases for the current phase to start producing. A pull is e.g. created by the client specifying a need for a certain product. This triggers the activity of producing this product to the specified characteristics and quantities.

In the context of knowledge and information sharing, this means that information needed in one phase of a project needs to be requested in order to achieve a 'pull' (Ballard, 2000). To put this into the frame of this report, the construction phase needs to 'pull' information from the design phase, by providing information regarding the need in the production phase. This allows the design team to create construction documents that the production team are willing and capable of producing in the construction phase. The described system is visualized in figure 3.9 showing the difference between a 'pushing' and 'pulling' system between design and construction. The pushing system (on the left side) shows the design team producing designs and solutions that are then sent downhill to production. However, the designs do not fit the need of the production. In the pulling system (to the right) the production teams are pulling the correct design solutions from the design by showing their need for specific solutions.

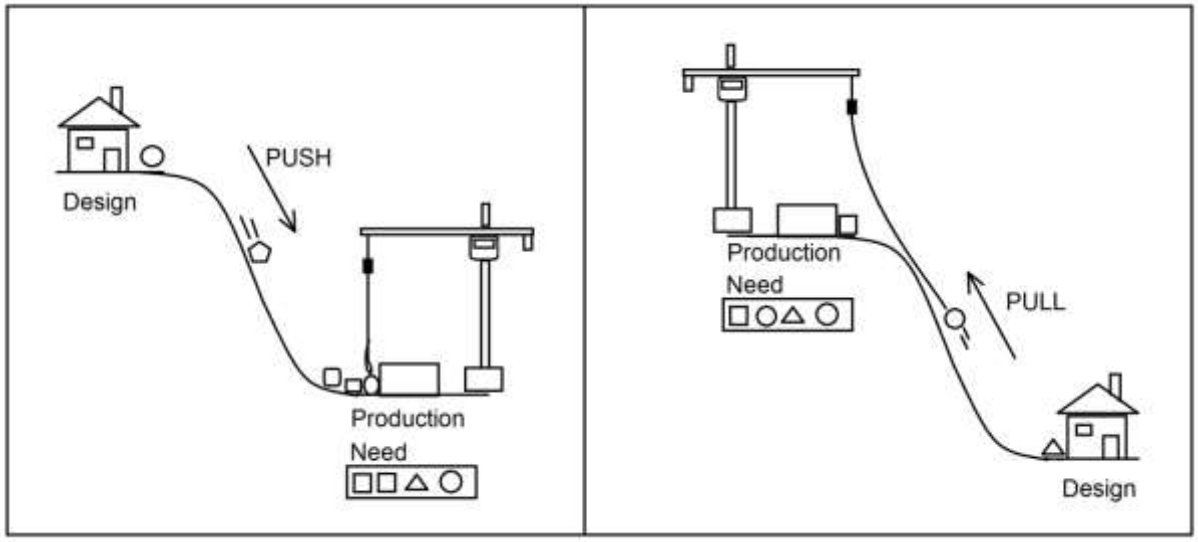

Figure 3.9: Inspired by Ohno Taiichi, Toyota depiction.

However, this works both ways, the design phase needs to 'pull' knowledge and information from the place that has the most experience. This means to draw knowledge from the construction phase that is useful in the design phase.

The 'pull' in project planning in Lean design, is created by adapting a method and utilizing tools that are fit for the dynamic nature of the projects in the construction industry. These methods need to allow for a 'pull' to be created in information and services between professions or disciplines in the design group, as well as between phases of the construction process. A relevant tool for creating this 'pull' in the design phase is the Last Planner System introduced by Ballard (2000) described below.

Last Planner System ™

Glenn Ballard has stated that: *"All plans are forecasts, and all forecasts are wrong. The further into the future we try to forecast, the more wrong we will be. The greater the level of detail we try to forecast, the more wrong we will be."* (2014). Therefore he developed the LPS in order to increase the reliability of the planning by involving those who are going to be carrying out the tasks planned. Ballard (2000) and LCI (n.d.) describes the approach of the LPS through five steps:

1. *Master Scheduling*: Identify and schedule main milestones and events e.g. Building phase transitions, completion and delivery.
2. *Pull Planning*: The notes promising a delivery of information or action, are put in the 'planning wall'. Starting at the milestone for project complete, the notes are planned in reverse order, creating a 'pull' of tasks. At this point, it is essential that the information given on the post-it is accurate, in regard to duration and timing. The accuracy is important, in order to be able determine to what activities to add buffers and create a more reliable schedule.
3. *Make Work Ready Planning*: When the schedule is reworked and set, the 'make work ready planning' stage establishes the task delivery certainty by going through the tasks that lay ahead and determining that the task has acquired the information needed in order to perform the task as scheduled. This is most commonly done 4-6 week advance,
4. *Weekly Work Planning*: At the start of every week a small meeting is held in order to establish that the scheduled activities agreed upon in the Master-, Pull-, and Make ready - plan will be performed. At this stage variation from the schedule should be minimal or as a result of a large unforeseen disturbance. The task can be split further in order to ease follow-up and overview of progress.
5. *Learning and measuring*: The last stage is feedback, this is done through measuring and follow-up of the tasks performed. Several performance indicators are taken to establish the progress of the project. These performance indicators are used to create an understanding of the projects current and overall performance for the group, and are also used for setting goals and achieving group learning.

The LPS aims to create a flow of knowledge and information in the production process that is based on a 'pull' in the system, as well as JIT, in order to create a higher reliability in the planning. By visualizing the planning and the contingencies between the workgroups, the LPS encourages the involved to 'pull' information and knowledge from one another during the design creation, as well as creating and transferring this knowledge and information; when, where, and to the criteria specified by the 'puller'. The LPS tool is founded on a high collaboration and trust between the project members. The members create a schedule that could be accomplished collectively by trusting in that activities agreed upon will be performed.

The LPS creates an environment where collaboration is essential by making the production team create the planning together. (Step 3: Pull Planning) This planning is based on the 'Should-Can-Will-Did' concept, visible in figure 3.10 (Ballard, 2000). In this concept, each activity in the planning is agreed upon collectively, and then the different disciplines will write down what they need in order to fulfill this activity and later, make a 'promise'; that they, and when they, can deliver it. This step embodies the trust needed between the design group members. Trust in that tasks that have been promised in the planning will be performed correctly and timely. Glenn Ballard (2011) describes this situation by saying that *"if reliability of work released between specialists is uncertain, this discourages investment in planning and preparation, which reduces performance"*. Meaning; that if the right knowledge is not present at the time of the transfer knowledge and information, trust between project members is lost, and so are the benefits of the LPS.

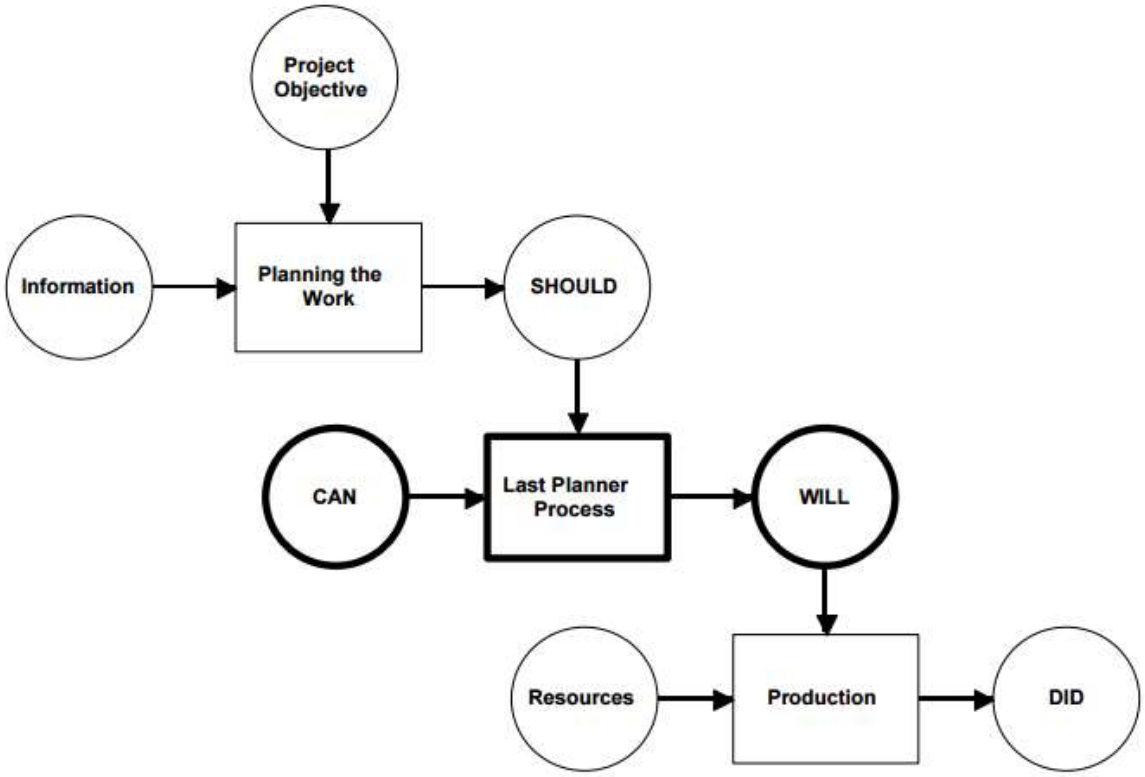

Figure 3.10: The Last Planner System (Ballard, 2000)

3.5.2 Co-location

This tool entails gathering the design team to work in a single space in order to gather all the knowledge and information obtained by the members in a single confine (Liker, 2009). The face-to-face communication that occurs in the co-located space increases the possibility for transferring knowledge through socialization and externalization as described by Nonaka (1994) in chapter 3.1.1. Therefore, facilitating collaboration through co-location increases the informal communication, e.g. exchanging stories and experiences, within the group (Karrbom, 2013).

3.5.3 Collaboration

This concept entails enabling the design team to work towards increasing the sharing of knowledge and information between them. To increase collaboration several methods can be used; design group meetings or the use of visualization tools are the approaches described by the literature (Liker, 2009; Kent and Becerik-Gerber, 2010; Nguyen, 2010; Bosch-Sijtsema, 2013; Kahnzode, 2015).

Design group meetings use co-location to facilitate the sharing of knowledge and information and thereby increase collaboration. A concept used by Toyota is: BIG Room (Liker, 2009). Khanzode (2015) explains the concept of Big Room as to create a co-located, on-site space where designers, builders and other functions can work together. In this space there is a room for the whole group to take part in the same activity at once, however it also contains areas designated for smaller groups to conduct discussions in matters that do not directly or currently concern the entire team. The objective

of Big Room is to improve collaboration by implementing a better team integration. Further stated by Khanzode (2015) is that an early integration of the different functions within a construction project results in a higher performing building in which the systems complement and supports each other instead of interfering with each other. This is supported by Nguyen (2010), expressing that: *"It allows downstream players... who have the most process-related knowledge and experience... to provide input to design phases"* (Nguyen, 2010, p. 20). This means that the knowledge and information exchange in this method is facilitated in such a way that it increased the collaboration with the "process-related" knowledge of the production team, which better aligned the outcome of the design phase with the needs of the production phase. The increased collaboration is also supported by the Macleamy curve, where the ability to impact functional capabilities (Curve 1 in figure 3.11 below) increases when applied early in the process (AIA, 2007). According to Kent and Becerik-Gerber (2010), involving key stakeholders in the project definition has several benefits: a higher support for the decisions made and solutions deployed, improved efficiency, less administration, exploration of many alternative solutions.

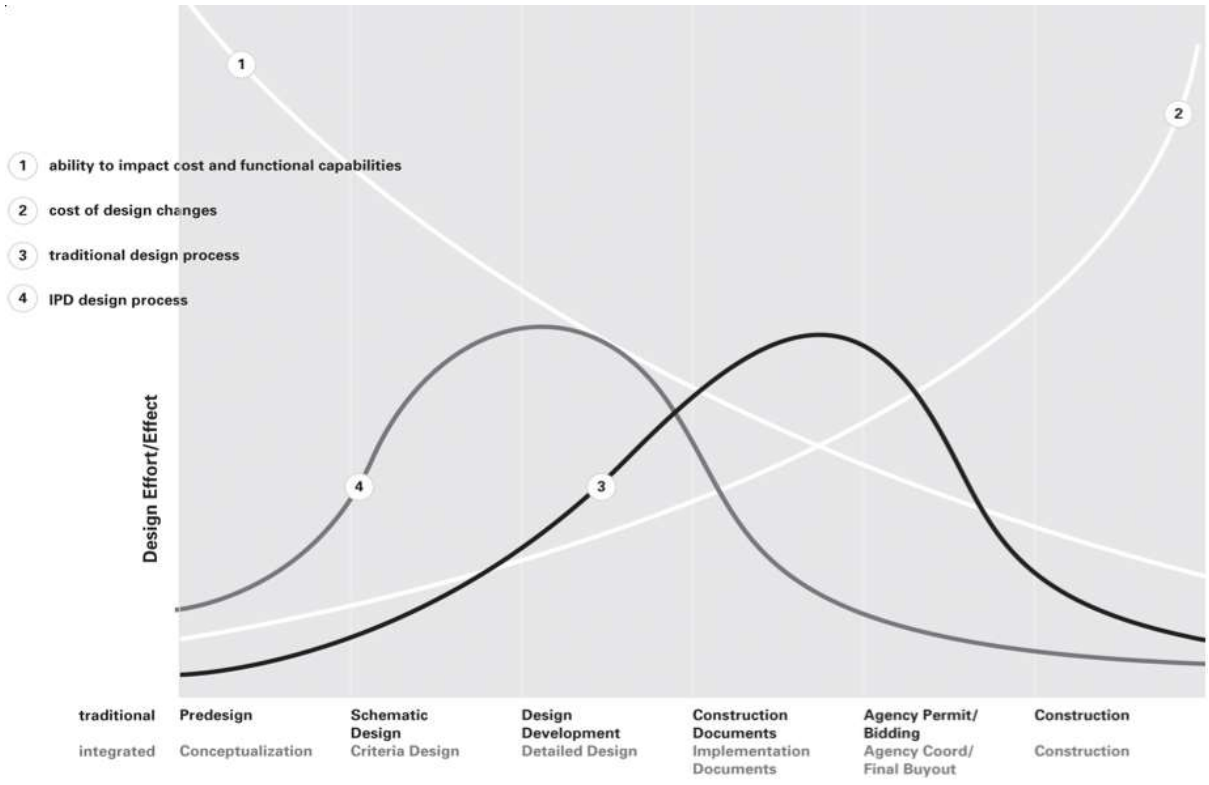

Figure 3.11: Macleamy Curve (AIA. 2007)

Visual tools are also described as helpful when it comes to meetings with big groups. The use of BIM models to visualize the building enhances interactions between team members (Bosch-Sijtsema, 2013). By also making the project planning visible through for example LPS, Landin et.al (2014) state that the decision making process becomes faster, the participation from all parties becomes greater, and the goals becomes clearer to those involved.

3.6 Critique towards Lean

In the reviewed literature, it is difficult to find a critical opinion about Lean. A great deal of the critique which exists, is directed towards problems occurring when not including the entire philosophy, or applying it in an incorrect or halfhearted manor. In relation to the Lean production mainly offers critical reviews of Toyota and TPS (Toyota Production System) which is the most popular example of implemented Lean production. A main critical point brought forth by Liker and Ogden (2011) and Mehri (2006) is ritualistic behavior, where activities are performed just because they are supposed to be performed. One example of this is reflections and suggestions conducted, not impacting future production or behavior, resulting in, among other, employee dissatisfaction and a lower work-place safety.

Reviewing the Lean construction literature, the aforementioned issue is highlighted by Green (1999) and Green and May (2005). Green (1999) criticizes the Lean construction literature, claiming that is inherently one-sided, using guru-like methods to forward their theory, as well as showing a lack of internal critique. Green and May (2005) concludes that, due to the diverse interpretations of lean, and 'leanness', *"The likeliest outcome is that managers give lip-service to the language of lean, whilst persisting with established practices and routines."* (p. 510). In reviewing this critique towards the literature, Landin et.al. (2014) claim that it poses a dilemma, where, if Lean is not implemented correctly, it is not Lean, and cannot be criticized for not working.

3.7 Implementation Barriers

Implementation of a Lean system is most often a large endeavor for a company, where reorganization of the organizational structure, processes, as well as education of employees and investment in new technologies and programs is required. In the reviewed literature several barriers are identified. Below, these are sorted into three categories to ease overview.

Change barriers: several authors have identified management commitment as a major barrier Koskela (1992) voiced his concern that the lack of management commitment will make other barriers more challenging. Sarhan and Foxs (2013) study confirmed this by identifying management commitment as the second largest barrier for implementation of Lean Construction. However Sarhan and Foxs study shows that a barrier that is weighted very close to management commitment is 'Cultural and attitudinal issues'. This barrier includes a resistance to change based in a will to keep the status quo. Changing the culture of an organization requires a high transparency, communication, and trust in order to break down these barriers (Sarhan and Fox, 2013). Koskela (1992) also advocates a 'focus on measurable and actionable improvements'. By doing so, motivation is found in the benefits of change, promoting a pro-change environment and continuous improvement. This is also beneficial for the understanding of Lean described in the paragraph below.

Educational barriers: Sarhan and Fox (2013) identified the main barrier for implementation as an inadequacy in, knowledge about, and understanding of Lean within the project organizations in the construction industry. If benefits of Lean Construction are not clear, or education on theory, tools and models inadequate, prohibiting involvement of all members in the organization, the philosophy will be at risk of being phased out or not implemented in specific levels of the organization (Koskela, 1992; Diekmann et.al., 2004; Sarhan and Fox, 2013).

Construction specific barriers: Diekmann et.al. (2004) focus on barriers related to Lean in the construction industry, that diverge from Lean in the production and manufacturing industry. They describe three hurdles in construction; (1) the lack of a overall repetitiveness of production, where

every project in construction is a unique combination of people, materials and knowledge, making the adjustment period for the methods and work possesses is minimized in the construction phase, locating more pressure on the design phase. (2) When working with many different parties in a construction project, the location, methods and work varies between projects, but also between companies. This counteracts the implementation of Lean, necessitating the implementation of Lean tools and methods to all encountered subcontractors. Diekmann et.al. (2004) suggests selecting key suppliers and subcontractors to ease the Lean implementation in this aspect. (3) Lastly the lack of control over the value stream is discussed, in the construction industry, in contrast to the manufacturing industry, the contractor does not generally choose the, site, design, or material, and is to a large extent limited to price-based relationships. By limiting the possible relationships like this the chances of collaborating with a Lean advocating company diminishes rapidly, increasing the efforts needed to implement Lean in the project and the organization.

4. Findings

This chapter will present findings from different parts of the study. It consists of two sections where the first uses information about the case study such as internal documents from the company. The second section presents the findings reported from the interview study and puts the different interviews together under the headings; Communication and Information Sharing; Collaboration; Perceptions and Descriptions of Roles; Experienced Difficulties and Solutions.

4.1 Case Study

The findings in this section are based on information gathered from one of the largest construction company's own documents such as descriptions of different roles within the company; guides for the design phase; and descriptions of the actual cases studied.

In order to address the research questions three cases have been selected, which are described in chapter 4.1.2. The intent is to explore how knowledge and information is shared between the design and production phases as depicted in figure 4.1.

The horizontal line represents the progression of a project in time. From proposal documents to production. The roles studied, are visible in the boxes labeled 'Design Manager', 'Project Manager', and 'Site Manager'. These managerial roles are the interviewed roles for the case study. The length of the box shows their involvement in the different phases of the project. These roles are described further in chapter 4.1.1. This study is conducted at a large construction company in Gothenburg, Sweden. The studied cases are ongoing domestic housing projects at the company. The criteria for the case selection are further described in chapter 4.1.2.

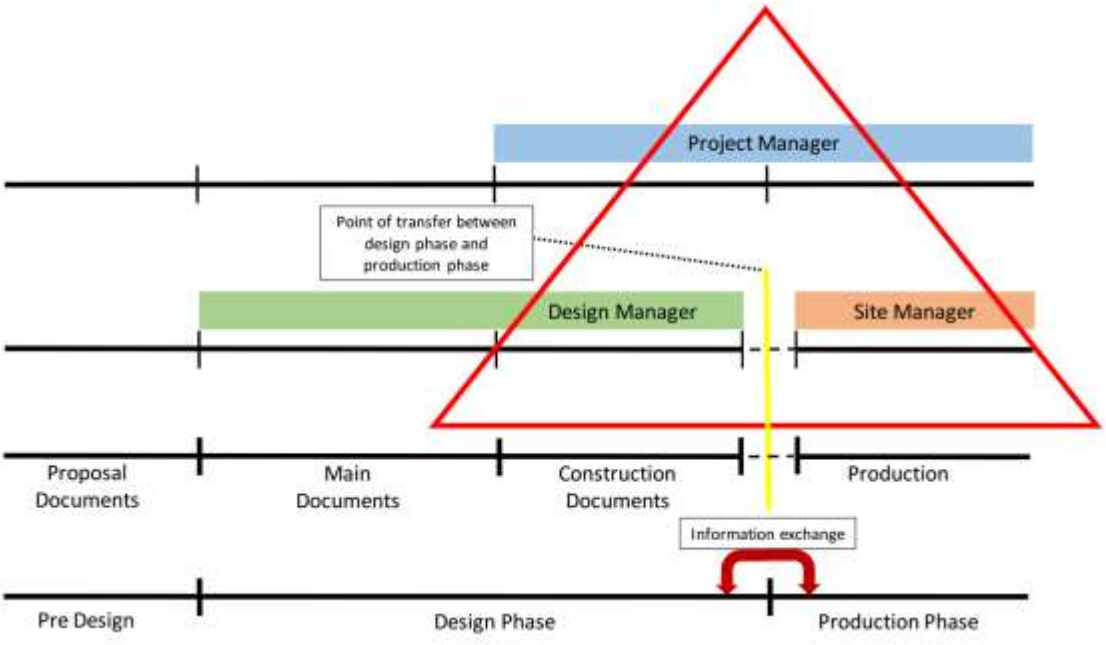

Figure 4.1: Visualization of the project process and the area of research.

4.1.1 Roles as Described by the Company

The roles selected for interviews for this study are based on their relation to the process of sharing knowledge and information between design and production. The three roles are directly affiliated with the handover and communication process studied, as shown in Figure 4.1. The selection of the specific interviewees was contingent upon the choice of cases. Below is a description of the specific managerial roles for this study.

Design Manager
Job description (Full description in appendix 2)

> *"Manage and delegate the design works in the project, from project definition to handover. Responsible for that the technical, utilitarian, economical, work environment, environmental, and time requirements are met. In addition, the work entails ensuring and verifying that societal requirements e.g. laws, are followed."*

It is the Design managers' role to lead the design team towards the common goal of producing construction documents, by fulfilling the predetermined values of the process and finished building. The Design managers are supposed to take measures to ensure the projects economy, project outcome, and time-restrictions.

The Design manager has a leading role in the completion of the construction documents prior to the handover. This allows them to have a large impact on the accuracy of the documents, and are also highly effected by the correctness of the documents. Documents with a low accuracy result in a heightened need for the involvement of the Design manager in the construction phase, in order to solve queries and, or making alterations to documents. However documents with high accuracy minimize the amount of problems in the construction phase, the Design manager can then focus on current projects.

Project Manager
Job description (Full description in appendix 3)

> *"Carry out the assigned project within the predetermined time-, quality- and cost-limits, as well as ensure that the client's expectations are met. Manage the work so that the assigned projects can be conducted with the highest possible efficiency."*

The Project managers role spans the design and construction phase as seen in figure 4.1. The Project manager has the final responsibility for the projects economy and management, and is responsible for; procurement of subcontractors, being the clients contact to the project and the organization, tendering review, etc. The Project manager therefor also has a high involvement in and effect on the accuracy of the documents produced in the design phase. As with the Design manager, the Project managers work is also affected by the correctness of the drawings. More accurate drawings result in fewer problems on site. This minimizes the amount of time spent solving problems that could have been prohibited in the prior phases.

Site Manager
Job description (Full description in appendix 1)

> *"Be responsible for that the current project, with or without subordinate officials, is performed according to construction documents with the highest possible productivity..."* (Appendix 1)

However, this is not a standardized document. In appendix 1 there are three versions of the job descriptions used for recruitment of Site managers. The description varies between projects, but has its basis in a list of activities that the Site manager should perform according to NCC's operational system description (NCC. 2015b) The descriptions are focused on the Site managers duties during construction, however a few also describe activities before and after construction. Listed below are a few of the duties of a Site manager that relate to the development and handover of construction documents.

- Planning the production phase efficiently.
- Go through construction documents.
- At an early stage choose method and material, with regards to efficiency, cost and experience.
- Communicating and incorporating 'lessons learned'.

The Site managers have important roles in leading the project in the production phase. Their role is highly affected by the accuracy of the construction documents. In order to create a more efficient handover between design and production, their input and feedback regarding the ongoing process is important.

4.1.2 Case Description

This chapter gives a short description of the individual cases followed by chapter 4.1.3, describing the Design meeting method used all by the cases as a way of implementing the Lean philosophy into the organization.

In the method chapter a list of criteria for the case selection was introduced, as shown below. The majority of these criteria are straight forward. The Design meeting system from criterion 2 is described in chapter 4.1.3, criteria 1, 3, 4, and 5 are fulfilled through the descriptions in this chapter.

1. Domestic housing project
2. Design phase performed in the company's Design meeting system
3. Ongoing or concluded design phase
4. Geographically located in Gothenburg and surrounding urban areas in Sweden
5. Same preconditions for involvement of site personnel in construction documents.

Below a brief description of the three different cases will be presented:

Case 1 – The first case consists of the second leg in the project as a whole. The project will produce 82 apartments and it is estimated to be completed at the shift of the year 2016-2017.

Case 2 – Case number two consists of four buildings and the researched project is the second leg for this area of construction. This is one project of many in this area of the city. When finished, in spring 2017, it will house 113 apartments.

Case 3 – The third and final case consists of 24 town houses in four different settings. This project is set to be completed in late 2016.

4.1.3 Design Meeting System - Implementation of Lean Philosophy

One of the criteria for the case selection was that the project uses the Design meeting system implemented by the company. This method is an attempt to facilitate collaboration and enable

knowledge and information exchange in the company's design phase. This chapter will briefly present the Design meeting approach in order to create understanding of the methods and tools used.

In the company the use of the Design meeting system started in 2011, in order to meet the rising demands productivity and project outcome goals put forth by clients, the general public and, internal pressures. Today, 2016, all domestic housing projects in the company use this method. The Design meeting system aims to facilitate the design team through standardized work practices and allowing multidisciplinary consultants to work collocated during the design phase. Standardized communication, problem solving and planning procedures, reduces waste (time not spent adding value to the product, process, or client), thereby improving the outcome of the process and ultimately the value of the project for the client. However, involving the 'right' personnel with the 'right' knowledge at the 'right' time, is a complex task.

The Design meeting system has its foundation in Lean construction (Chapter 3.4) and consists of three pillars: Virtual Design and Construction (VDC), Co-location, and Visual planning, as visible in figure 4.2 below. These concepts and tools are described further, in the three following chapters.

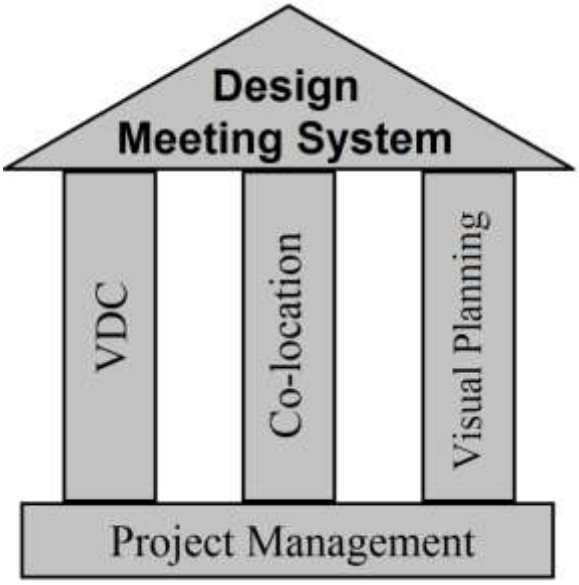

Figure 4.2: The three pillars of the construction company's Design Meeting System

VDC
Through the use of VDC, the company aims to implement modeling, visualization, clash detection, and more in the design phase of the project, but the degree if implementation varies between projects. During the Design meetings VDC is used in order to find problems in the models that need to be solved. These can be clashes between different parts of the building or consultants work. The model is used as a basis for group understanding and analysis of the discussed problem occurring in the model, in order to collectively find a solution to a problem.

Co-location
The co-location pillars goal in the Design meeting is to increase collaboration and communication between the consultants involved. These are usually all consultants hired for design work: earthworks, electrical, plumbing, ventilation, architects, etc., but also consultants from the production phase as

well as the Project manager. The co-location is used approximately one day per week in each project. The area used for co-location, must be large enough to house the design team. In addition to this, experience has shown that it is also beneficial to have smaller rooms available for smaller, more detail oriented discussions between a few parties.

By co-locating the design team, the construction documents and design solutions produced are aimed to be agreed upon between the consultants as well as the production team. This should ensure the documents accuracy as well as the fulfillment of the values and demands set forth by the client. In order for the co-location to have the desired effect on the outcome, it is essential that the involved parties understand the importance of their presence in the Project Studio, and that all are accounted for at each Design meeting. Within the co-located confines, visual tools are very helpful. The company states that the use of visualizations of the project and, or the end product, is helpful with the decision making process and the handling of information within the project. A design meeting usually starts at 9:00am and ends when the design team has discussed and solved the current issues. The end time therefore varies between lunch and 4:00pm. The design manager leads the discussions through the agenda of issues and steers the conversations towards solving the issue at hand. If an issue needs further work or information from a party that is not present, which is quite common, the parties post notes on the visual planning board (described further below) showing what information is needed from what consultant at what time. The times and informational content is agreed upon during this planning process. If a consultant or other member is not present at this meeting, they are contacted by phone or email to confirm their contributions, however this slows down the planning and the work performance.

In the Project Studio two main visualization tools are:

1. Using VDC. To visualize the building makes interactions between team members better.
2. Through the use of Visual planning, the schedule with post-it notes containing deliverables and requested information for the different practices are posted on a large visible surface. This schedule also contains project specific deadlines.

Figure 4.3: Example of the Pull Planning schedule used in the cases.

Visual Planning

Visual planning gets its name from the fact that the planning is posted on the walls of the Design meeting room as seen in figure 4.3. The purpose of the Visual planning in the Design meetings is to allow the entire design team to contribute to, and influence the planning, as well as getting an overview of the contingencies between the activities in the project. The scheduling uses a system where all the involved consultants use post-it notes to write down what task is to be conducted, area the task is located in, which documents the task is considering, and what information or input is needed from other parties to complete the task. These tasks are put on the timeline and organized together as seen in figure 4.3 above. To organize these tasks, 'Pull'-planning is used throughout the planning process. In short, the design team starts by posting the final task and then work their way backwards through the project, adding activities and specifying the information and knowledge needed when and where, in order to perform these activities. This work process strengthens the understanding of contingencies and respect for different consultants work. This planning process results in a plan where activities are not performed before they are requested, and then to the specified requirements, minimizing the need for rework and overwork.

The visual planning process also results in (1) the ability for all stakeholders to affect design solutions at an early stage, (2) prevention of misunderstandings because of the visualizations of the documentation creating an overview increasing the understanding in the project, and (3) faster problem solving due to the high amount of knowledge present during the Design meetings. All of these positive outcomes should also; with the right focus on customer value, shorten the time frame for the project.

4.2 Interview Findings

This chapter will document findings which came up during the interviews. In total eight different interviews have been carried out. The interviewees represent the following three roles; Design manager, Project manager and Site manager; from within the three cases studied. The focus of this chapter is to describe the different roles' perspectives' and not the individuals themselves. The interviewees will therefore be referred to as DM (Design manager), PM (Project manager), and SM (Site manager). The codification also includes one of the three cases which gives e.g. DM1 for Design manager in Case 1.

4.2.1 Communication and Information Sharing

Communication is an essential part of any organization; large or small, continuously running or project based. For the cases studied, the interviewees all explained that there are three main channels of communication used within a project. These are; the design meetings, emails, and phone calls. Looking closer at how the different means of communication are used within the cases the interviews revealed that 'face to face' communication through meetings, where SM, DM and PM are all present, is used almost exclusively in the design phase. However, when the project shifts from the design phase to the production phase the main communication channels used are emails or phone calls, but DM2 and DM3 wish for as little communication as possible in the production phase; *"the less communication during the production phase there is, the better. Because then there have not been that many errors in the construction documents"* (DM2). However the communication does not always run smoothly; *"you should not email the production because you will not get an answer, but it is always possible to phone them*" (DM1). The preferred channel of communication varies between individuals.

Within the Triangle (figure 5.1) there is a great deal of information sharing and communication taking place. All of the three roles need to share information between one another but someone should also be responsible for the boundary spanning communication. The general opinion among the interviewed managers of who should be responsible for the communication is that it should be the Project managers task. This due to the fact that the PM role is a part of both the design phase and the production phase, as well as having an overall responsibility for the project. The exceptions from this opinion in this study are SM2 and PM1/PM2 who suggest that the Design manager should be responsible for the communication. However, SM2 also believes that the Site manager should be partly responsible, and should take over the responsibility of the communication when the project moves from the design phase to the production phase. This differences in opinion are suggested to occur because ”*it is often the Design manager that takes responsibility of the communication in the design phase"* (DM3). The disagreement of to whom the responsibility actually belongs, shows that this may not be clearly stated in the role descriptions.

4.2.2 Collaboration

To use all the necessary resources available in the design process in a project, creates the opportunity for the project to have as good a performance as possible. Having the focus of this thesis in mind, the interviewees described what they considered to be necessary for a greater collaboration within the projects. All interviewees pointed out the importance of participation from the production team, with the Site manager as a key figure, in the design process; *"much of the important knowledge exists among the workers at the construction site, therefor it is important to get their input"* (DM1).

In the cases studied, the collaboration between the design team and the construction team in the design phase has differed from case to case. Most of the collaboration is taking place during the design meetings which are held once a week during the design phase. These design meetings offer an opportunity for all consultants in the design team to meet, and together come up with the best solutions possible for the project. It is stated by all interviewees that it is preferred that the Site manager and the Project manager should attend these meetings as often as possible so that the views and opinions of the production team can be considered when making the decisions of e.g. framing systems, materials, etc., and also so that the production team can create an understanding for the project that lies ahead. This aspect of attendance from representatives from the production team has varied between the cases. However it is expressed for all cases that a higher collaboration would be useful. Reasons for lack of collaboration in the Design meetings are according to all interviewees that there are many tasks put on the PM and that the SM *"does not have time between projects"* (PM1/PM2, DM1). This has caused some disturbances because *"the Project manager has not been sufficiently present at the design meetings to give support to the Design manager"* (DM1, DM2). There are also differing opinions of when the Site manager and/or the site foremen should be involved during the design process. Currently the aim is to include the production team in producing the construction documents but it is seldom carried out to the extent wanted or needed. Most interviewees, however, see that it would be beneficial to include some key persons from the production team as early as the main documents. In the main documents the fundamental decisions are made, e.g. what type of framework or foundation should be used and if the production team could influence this then they would be *"building what they want to build"* (DM2). However, PM3 did not think that it would be necessary for the production team to take part in producing the main documents, *"most systems for the structures are standardized so they do not have to influence the choice of structure"* (PM3).

Between the design phase and the production phase there is one point of transfer. This transfer mainly consists of getting all the information and knowledge from the design team into the production team, but it also has to be received and understood by production. To make this transition as smooth as possible it is important that all the documents that were produced in the design phase maintain a certain accuracy. A method that is always used to detect errors in the documents is that parts of the production team and sometimes the Project managers review the documents and send notes back to the design team before the final document is created. Even though it is considered important that the documents are reviewed, *"the more people that review the construction documents the better they become"* (DM1, PM1/PM2), the actual drafts that are sent out to be reviewed are sometimes missing out on details, *"sometimes the construction documents are somewhat substandard"* (SM2). There are also some tendencies of a difference in opinion regarding the importance of the process of reviewing the construction documents, *"the production team do not review the documents to help the Design manager, it is to help the project to the best possible result"* (DM1). Still, it is sometimes also the time allocation for the SM that has to become better, *"sometimes the site management prioritize their time in the wrong way"* (DM3). The actual point of transfer between the two phases is structured in a way similar to a regular design meeting, but is focused on the transition into the production phase. The general opinion regarding this single transition meeting is that it is sufficient as it is, as long as the production team has been able to participate in the design phase and thereby has created an understanding for the project. However, one remark that stands out, is that one of the SM states that one transfer-meeting would be sufficient even if the production team would not participate in the design phase, but there would *"be a greater number of errors arising in the production phase"* (SM2).

4.2.3 Perceptions and Descriptions of Roles

When it comes to how the roles of the Design manager, the Project manager and the Site manager should be executed and described, few of the interviewees knew how the Project managers roles were structured. PM1/PM2 and PM3 know that their tasks are, *"being the link between design and production"* (PM1/PM2). However, they have different approaches and focus in their daily work. It is described that the Project managers should have *"an overview of several projects and act in different parts of the projects"* (PM3). But PM1/PM2 focus a lot on the production and helping the Site managers while PM3 seems to be keeping a wider scope of the projects. The Project managers also have an important task in the design phase; they should be: *"making connections to previous projects to avoid that problems reoccur in project after project"* (PM1/PM2), and this makes it difficult to understand why there is lack of participation in the design phase. When the Site managers and the Design managers speculated in the actual 'definition' of a Project manager none of them had a definite answer. In general, the Site managers thought that the Project manager should focus on the construction site and help the Site managers, and this stems from the fact that the Project managers had a previous career as a Site manager. But the Design managers wanted the Project manager to be the link between Design manager and the construction site and have more of an overview of the projects, which is the same point of view that is described by the Project managers. Because of differing approaches between the different Project managers and especially in different projects, the Design managers share the opinion that the *"support and knowledge of the Project manager is lost in the design phase"* (DM1, DM2).

The Site manager role has existed in its current state for some time. The changes implemented during the last years have been adding some administrative tasks. All Site managers believe that their task is to; keep track of the personnel, taking responsibility for the economy of the project, taking care of the delivery plan to the site and keeping track of the schedule for the project. There is always a lot going on at the construction site and therefor it is important for the Site managers to *"keep the logistics on the construction site working properly"* (SM3). As mentioned earlier an important task for the Site managers and the production team is to review the drafts of the construction documents produced in the design phase. This task seems huge if the Site manager does not have very much experience as a Site manager, *"how to attack these kind of tasks is something everybody learns with experience"* (SM2). Generally the role of the Site manager is interpreted in the same way by all the interviewed managers. However, just like the lack of presence of the Project manager in the design phase mentioned in the previous paragraph the Site manager does not always participate in the design phase in a satisfactory manner according to the Design managers.

Last but not least, the Design managers have the role of head of the design phase, keeping the whole design team running, and making sure that the collaboration within the team functions properly and according to schedule. Although one of the Design managers is also head of the group of Design managers, which brings an extra layer of personnel related tasks to the table. It is described by, not only the Design managers, but all interviewees, that one of the more important tasks for the Design manager is to make sure that all parties and consultants that are needed in the design meetings, both internal and external personnel, attend the design meetings. The Design managers themselves view the Site manager and the Project manager as playing an important role in the design phase, and want their help when discussing topics related to the construction site and the production team. However this is only possible in a satisfying manner if the Site manager and/or the Project manager attends the design meetings. The general interpretation of the Design manager role is similar for all interviewees, the Design manager is the head of the design phase and responsible for the transition into the production phase.

4.2.4 Experienced Difficulties and Solutions

Throughout the interviews there have been several minor and major difficulties brought up but also several possible solutions pointed out. The solutions that have been pointed out have been similar, between the roles. In this chapter, the major difficulties and solutions are presented.

One of the issues frequently brought up during the interviews, was the perception and knowledge of the different roles. An example is the role of the Project manager which is commonly known by the interviewees to be the link between the design team and the production team and in addition to this, having the overall responsibility of the projects assigned to them. However, even if the overall perception of that role is clear to all the managers within the Triangle (Figure 4.1), the interpretation of what focus the Project manager should have, differs. The Site manager and the Project manager generally think that the role of the Project manager should be focused on helping the production team while the Design managers stick to the more overall description of the Project manager being the link between the design and production phases as well as having the overall responsibility of the projects. When a link between the design team and the production team is missing, the mentality of *"us against them"* (SM1, DM3) is more common. This mentality is seen by the managers as counteracting the aim of having a wide collaboration between the two phases. Several of the interviewed managers also state that, in order to have an efficient collaboration and counteract the 'us against them' mentality, it is necessary to have an understanding of the other teams tasks, responsibilities and preferences within the project.

To be able to have a successful project process, all the interviewees emphasize the importance of all the roles involved, participating in the design phase. The Design managers see many advantages with having the production team in the design phase, and *"if the Site manager cannot be present when the foundation is discussed then the production foremen that has responsibility for the foundation could attend in the Site managers place"* (DM3). Most often it is aimed towards including the production team when the construction documents are prepared and created. However, the Design managers also claim that there would be advantages with having the production personnel take part in the process of producing the main documents as well, *"this is where the systems for the foundations, and the body of the building is set"* (DM1). The earlier the production team is included the more they can influence, and in that way it is possible to get the systems and solutions that the production team wants to use in the production phase. As mentioned earlier, the attendance of Site managers and Project managers at the design meetings differ from project to project and this results in lack of support toward the Design manager. The Design manager on the other hand points out that the site and Project managers do not always have the time to participate properly and that this must change so that there is time available to put into the design phase. The company is trying to help the Site manager to participate in the design phase, *"the Site manager is supposed to have two to four months between projects so that they can familiarize themselves with the upcoming project"* (SM3, PM3). Also there are things that the Site manager can affect, for example *"form the schedule somewhat lighter in the end of the production phase so that it is possible to spare one or two days a week to get into the next project"* (SM3). All in all the importance of representatives from the production team in the design phase is pointed out several times by all interviewees and it is something everybody wants more of.

Another problem brought up by the interviewees is that knowledge stays with the individuals and the sharing of knowledge is not sufficiently used. At the end of a project, all projects have a follow-up-meeting where all the difficulties during the project should be brought up, discussed and noted, so that the same errors or problems do not occur in future projects. However, these meetings are not always

conducted due to 'lack of time'. However, if the meeting is carried out the outcome of the meeting is often not enough to fulfill the criteria set for it. SM1 and SM2 state that having one single opportunity to document errors results in many problems and *"solutions being forgotten and never documented for future projects"* (SM1, SM2), which leads to the same solution for a problem having to be invented time and time again. To improve the project process DM2 has implemented a trial program of continuous feedback meetings that take place once every three months. The three month interval could change to be longer or shorter depending on the project needs. This is not an established project process within the company, however, DM2 states that this process has helped the project and that if DM2 could choose, this would be standardized for all projects.

Despite the focus of the interviews not being the economic gains, but the outcome of the project itself, all eight interviewees were asked if they believe that the project would be more profitable if changes like including the production team more in the design phase were to be implemented. There was a general consensus among the interviewees that the cost of extra personnel participating in the design phase would be small in the comparison to the gain of not having to change designs in the production phase. PM3 commented this; *"all the time that is spent on planning and design we will make up for in problems not occurring in the production phase"*. DM2 made a rough comparison of changes made in the design phase and in the production phase; *"what costs 1SEK to change in the design phase costs 1000SEK to change when the construction work has started"*. This was an estimation made by DM2 to put the costs into perspective.

5. Discussion

This thesis is conducted in order to identify issues regarding knowledge and information sharing between the design phase and the production phase in a construction project within one of the largest construction companies in Sweden. This was done through examining the collaboration between the Design manager, the Project manager and the Site manager in the process and detecting affects on the project outcome.

In this chapter the findings are discussed and used in relation to the theory, this to compare and link the theories and findings. Through this discussion the authors aim is to extrapolate the conclusions reached in chapter 6.

All the interviewed managers state the importance of collaboration between the design and construction phases. However, the will and initiative to enable knowledge and information sharing is not shown through action.

5.1 Knowledge and Information Transfer Between Design and Construction

The knowledge and information is barely shared between the design and production phases in the current construction process. This is seen through that many problems are first discovered in production, requiring a high level of last minute problem solving in this phase. These are problems that possibly have been handled through better knowledge and information sharing between the design- and production phase, which also depends on the collaboration between the Design- Project- and Site managers. This shows that there is a lack of 'Pull' between the phases. The production is not pulling design solutions that are implementable in the construction from the design phase. However, if the production phase is considered the 'client' of the design phase, it can also indicate that the design phase is not listening to what the 'client' wants, in order to create the best value for them (Liker, 2009).

A part of the situation described above is that the involved parties are not willing, or simply do not take advantage of meetings where knowledge and information transfers can take place. It is somewhat indicated by the Design managers that the Project managers do not participate to the extent desired in the parts of the design phase where the knowledge and information is transferred. The lack of participation depends, according to the Design managers, on the fact that the Project managers' time allocation is directed more toward the production phase and supporting the Site managers. Considering the Project managers' background as Site managers they might feel more comfortable in the production phase and working close to the current Site manager. The will to engage themselves in the design phase to a higher extent does not seem to exist among the Project managers. A unwillingness to participate in the design phase suggests that the design teams' culture and the production culture differ in ways which makes the barrier of understanding and switching between the two difficult (Dainty et.al., 2006). Low participation in the design phase could also be a result of unfamiliarity with the design phase among the Project managers who tend to show an uncertainty to make, and affect decisions in the design phase. The unwillingness to take part in the design phase could be explained thus: when crossing in to a new phase of a project, it is easier to dissociate from it and keep a low profile, rather than enter a new culture or phase where there is a risk of failing or showing lack of knowledge. This inhibits the willingness to and efficiency of the knowledge and information exchange.

The managerial roles include communicating with different stakeholders to overcome boundaries. This activity is a large part of their duties, as strengthen by Brion et.al. (2012). The lack of this activity in the communication coordination between the three managers, results in the Site-, and the Design manager finding themselves in charge of their primary phases respectively. Similar to the Project manager, this results in an increased familiarity toward one of the phases. The attention toward the phase in which the person is not responsible therefor tends to be weaker. This suggests that there is unfamiliarity among the site and Design managers, both in the actual work of the 'other' phase but also of the difference in culture (Dainty et.al., 2006). Although the opportunities to communicate seem to exist, the roles do not tend to take advantage of them so that knowledge and information sharing happens in a way that satisfies the knowledge exchange needed in order to create a process where the knowledge delivered JIT (Liker, 2009). This shows that the responsibility of communication, and need for the phase-specific knowledge in the process is not clearly stated, or interpreted differently among managers (Carlile, 2002). The responsibility is not only to create a sufficient number of occasions for knowledge and information sharing but maybe more to make sure that the time spent on the activity is used to its full potential. Helping the usefulness of the knowledge sharing would be focusing on that the information needed for making a decision about a specific task should be provided to the design team during the decision making process. However, the design team should also request information from the production team to be delivered at this time, in accordance with JIT (Liker, 2009); the right information, at the right place at the right time.

The lack of communication occasions utilized may also stem from that the Site-, and Design manager do not want to push the other party around in 'their own' phase, and make them look bad. On the other hand it may also be the reversed, i.e. not being able to contribute because of the perceived lack of knowledge within the discussed matters. This is considered embarrassing and therefor risks of ‘losing face’ in front of others, causing a person to refrain from participating in situations where this may occur. This fear of 'losing face' causes the person to fail in partaking in tasks or discussions that do not lie within the person's own field of expertise. This embarrassment felt may also stem from a lack of trust between the design team members or between the phases. If one does not feel a ‘companion trust’ as described by Newell (2009) for the other project members, the feeling of lack of personal relationship may increase the perceived embarrassment or loss of face. When the responsibility for the communication between the managers in the Triangle (Figure. 4.1) is missing, the Site manager and the Design manager communicate directly with each other and not via the Project manager. This, despite that the Project manager is generally believed, by all interviewees, to be responsible for the communication between the three parties. This indicates that the Project manager's presence in the communication and the collaboration work between the three roles is insufficient. The communication between the Site manager and the Design manager mainly takes place via phone calls and consists of short and direct questions regarding the construction documents or specific solutions at the construction site. The increased communication between the Site-, and Design manager can be interpreted as compensating for the perceived lack of guidance from the Project manager. Even if the Project manager role is bypassed in the information chain during the production phase the problems due to lack of communication continue to occur. Despite the communication link between Site and Design managers the responsibility for the communication is still not present. The knowledge and information sharing which should occur in the design phase to avoid errors during the production phase is replaced by short conversations when the actual problem surfaces. This suggests that the problem solving is to a wide extent taking place in the production phase as a short term solution rather than in the design phase which would be a long term perspective. Hence; it is important that the responsibility of the communication is assigned to one specific role.

To be able to make continuous improvements within the company, the feedback between the two phases is important throughout the project (Liker, 2009). However, this is not implemented. The current process includes a feedback meeting at the end of every project, where issues that were found in the production phase are revealed and discussed. However, there is a risk that problems that were solved on site, that were not large enough to be documented will not make it to this meeting before being forgotten. Problems found in the production phase will therefore not reach the design team. This strengthens the implications of lack of communication throughout the project process. The lack of possibilities to communicate the errors occurring in the production phase reinforces the lack of responsibility, recording and communicating the issues and solutions that have surfaced during the production phase. With no specific role taking on the responsibility of documenting the possible improvements that can be made, the project will not learn from these issues. This suggests that the advantages of a working system of continuous feedback is not considered or emphasized enough, which also adds to the perceived lack of knowledge and information transfer between the phases. If a continuous feedback system is not used the knowledge of the individuals involved in both phases is not utilized to a wider extent. This together with the lack of knowledge and information sharing between the design team and the production team results in not finding the best solutions and also more errors occurring during the project process.

5.2 Collaborations Effect on Project Outcome

In chapter 5.1 it is discussed how the current knowledge and information is transferred between the design and construction phase. Building on this, the following chapter will discuss implications of this transfer in relation to how it affects the outcome of the project.

Lack of knowledge and information transfer between the design and production phases induce that the production team is not receiving the needed information to carry out the construction work. The issues that are transferred between the phases are often related to the solutions implemented for how so solve a certain construction or building process. E.g. the construction documents show no signs of problems for a certain building component, in the design phase. However, on the construction site, the physical act of completing the task as described in the construction documents could be very difficult or impossible to implement.

In order to implement the process- and design solutions that the production team can, and wants to build, the production team's knowledge needs to be implemented during the design phase, at the right time to alter the design solution implemented, as confirmed by the theory of JIT (Liker, 2009). For cases like the one described above, this means that the knowledge from the production phase needs to be shared before the decision for a specific design solution is taken. The knowledge and know-how of the production team will at this stage improve the outcome of the specific solution, the construction documents, and in the long term; the project. In other words, the production team participation and contributing with knowledge during the design increases the Pull for the better solution being created in the design phase and increases the outcome of the project. A lack of this Pull will allow the design team to continue implementing suboptimal solutions that create problems in the production phase.

Furthermore, a large part of creating a Pull for the optimal solutions is the possibility to give feedback; not only during the design phase, but also during the construction phase, as supported by Ballard (2000). To have opportunity to meet with the Design manager and reveal issues that have been found during the construction of the building. However, as described in chapter 5.1 this is not a part of the current process, which results in the design solution chosen in the design phase, that did in fact create problems in the production phase will not be recorded as suboptimal by the design phase.

This most likely leads to that the design team will implement the same solution in other projects, decreasing the outcome of future projects, and prohibiting the project organization to learn from its mistakes (Liker, 2009).

There is therefore a negative spiral created in the transferring of knowledge and information. First the design phase implements a solution that the production phase does not, or cannot build. This solution is implemented because there is no knowledge present concerning the construction design during the design meetings. Secondly, there is no backflow of information telling the design team that this particular solution is suboptimal, missing out on aspects of LPDS (Koskela et.al, 2002). Therefor the solution is implemented again. This negative spiral adds to the 'us against them' mentality where the production team keep fixing the problems that the design created, and complaining about how *they* never learn. While the design team keeps thinking that *we* came up with a great solution. This gap created between the two phases may diminish the communication and collaboration even further, impairing the outcome of the design solutions, the construction documents, and the outcome of the project.

6. Conclusions

The purpose of this report is to investigate the process of the handover of the project and construction documents between the design phase and the construction phase in domestic housing projects, and to explore how these processes affect the outcome of the project, and the handover. This is done through answering the following research questions.

RQ1: How is knowledge and information transferred between design and construction?

The knowledge transfer between the design phase and the production phase is conducted through a handover-meeting. This handover-meeting is a meeting between with the three managers; Design-, Project-, and Site manager, where the projects construction documents are discussed and physically handed over to the production phase. In the meeting the managers discuss issues encountered during the design phase, the design solutions, as well as issues that have been identified in the review of the construction documents. However in order to be able to conduct this handover as a single meeting, a high degree of involvement in the design phase is needed.

The current knowledge and information exchange between the design and construction phases is conducted through the design meetings where the design team, including representatives from the production phase, converge to iron out the details of the construction documents used in the production phase. In the design phase, the design meetings are the intended primary mode of communication and collaboration. In the production phase the primary mode of communication is emails and phone calls, as well as a post-production review meeting. The process is functional, however not used as intended. The findings show that there is a need for further improvement in order to improve the outcome of the project process. A focus towards sharing the knowledge and information needed is not strong enough; hence there is also lack of knowledge and information towards making better decisions in the design phase. The interviewees emphasize that higher commitment to the participation in the design meetings, is of great importance. This to be able to share the knowledge and information needed in the design phase.

RQ2: How does the collaboration between these roles affect the project?

The collaboration between the managers in the handover of the project between the design phase and the production phase affects the project greatly. The communication between the managers aims to allow knowledge and information to flow between the phases during the handover process, the design phase as well as the production phase. However as stated in the previous research question, the process is not functioning as intended. The low participation in the design meetings and the current feedback process are affecting the project in a negative manor.

This study has observed that there is an unwillingness to attend design meeting. This is likely brought on by the culture clash between the phases. A fear of losing face or showing lack of knowledge increases the unwillingness to attend the design meetings and influences the projects ability to collaborate in the co-located meeting negatively. A lack of attendance decreases the knowledge available when making decisions in the design phase. Therefore, right knowledge is not available at the right time in the process leading to that the accuracy of the design solutions and construction documents decreases, and the amount of issues found in the production phase increase.

In addition to this, the current feedback process decreases the outcome of the project process by not allowing for a continuous feedback throughout the production process. This limits the amount of issues, identified in the production phase, that reach the design team. This, in turn, decreases the possibility for the design team to come up with an alternate solution before the task is performed, but also increases the likelihood that the same, suboptimal, solution is implemented in other projects.

7. Authors Suggestions

This chapter is dedicated to the authors' reflections and suggestions towards improving the project outcome. The discussion focuses on the perceived issues in project process in relation to the research questions and the theories researched. The suggestions are based on the Lean philosophy.

Firstly we want to address the issue of the three managerial roles pushing away the responsibility of coordinating the communication. The discussion indicates that the roles do this, because they feel like they have a lack of knowledge or experience from the other phase, and therefore it is easier to push the responsibility towards someone else, rather than risk showing a lack of knowledge. To counteract this issue the authors suggest that the three managers meet to discuss their roles, strengths and weaknesses and how they could lead the project together. This should lessen the 'us against them' mentality by defining the relationship between the managers, creating a tighter bond between them.

The mangers different interpretations of the roles also suggest that there is no one way to interpret the role descriptions. In addition to the collaboration, described above, to increase the understanding of the roles, we suggest that the company develop a more specific role description that should reflect the responsibilities of the roles towards the knowledge and information exchange between the roles and phases. These responsibilities should be more precise and less open for interpretation. This will create a more unified understanding of the boundary spanning necessary between the roles as well as with whom this responsibility of coordinating the information exchange lies. This should be done in collaboration with the managers affected in order to increase feedback from their observations of the current process. The authors suggest that the responsibility for the coordination of the communication be given to the Project manager, because of the role's organizational placement. The Project manager is involved in the project in both the design phase and construction phase and has the final responsibility for the project overall, therefor the increased communication between the roles should be in the overall project interest, and thereby also within the Project managers responsibilities. However, during the design phase we also suggest that the Design manager be given have a higher authority to summon parties needed in the design meetings.

Secondly, to improve the project outcome further, the construction documents' accuracy needs to increase. This is done through a higher collaboration and knowledge transfer to the design phase. We suggest that the company implements a general education in Lean for the managers and consultants who are a part of the design team. This should increase the understanding of the need for collaboration and co-location. In addition to this we suggest that participation of the Project manager and the Site manager is requested to the co-located design meetings during the design of the main documents, and required during the development of the construction documents. The attendance in the design phase should be required and made possible by the organization by increasing the time resources for the Project and Site manager to attend the design meetings, and specified in the project process description. The increased integration will allow for a higher transfer of knowledge to the design phase, creating a 'Pull' from the production phase for construction documents that contain design solutions that the production team is able to, and wants to build. In the long run, the increase in buildability will lead to an improved outcome of the project process. To this end, there is also a higher degree of feedback needed between the phases. A periodic backflow of information is needed throughout the entire process. For this we suggest implementing a feedback-system similar to the one described in use in Case 2, where the Design manager implemented periodic meetings for the duration of the project. The aim of the meetings is to increase the flow of knowledge by creating a pull between the construction and design phase. The meetings allow the Design-, Project-, and Site managers to be able to discuss issues related to the design or construction, which have surfaced between the meetings. This process is described as useful and appreciated by all involved, because it

allows the problems that are small or forgotten or not written down, to be noted by the DM and the design phase. This is information that would have been lost before the large post-project feedback meeting.

The solutions suggested in this chapter are:

1. The relationship between the roles needs to be defined and worked through with the managers.
2. The role descriptions need to be more precise in describing the responsibilities of the roles regarding the communication coordination.
3. General education in Lean philosophy and tools
4. The role descriptions should emphasize the importance of a resource focus toward the design meetings.
5. Higher organizational focus on managers participating in the design meetings.
6. Continuous feedback meetings during the production phase.

We believe that implementing any or all of these suggestions will improve the outcome of the project process by creating a learning project team, that not only drives the project forward, but that also continuously improves the construction process used in the projects by striving towards creating the best value for the client.

8. Further Research

In this study, there was a lack of information regarding the number of issues that reach the production phase from the design phase. Research should investigate the possibility of implementing a system for quantifying issues and the origin of these will directly indicate to the Design team when, and where a higher information and knowledge transfer is needed, as well as being able to track how well solutions design were in fact functional in the production phase.

It is inferred by the interviewees that the suggestions provided in chapter 6.1, are thought to have a economical benefit in addition to the improvement of the project outcome. To further the research conducted in this study, the authors suggest that additional studies researching potential improvements to the current process from an economic or time perspective should be conducted. This to identify if and what benefits, increasing the collaboration may have for the company.

Furthermore, the project process at the company contains several phase shifts where handovers and collaborations between managers of different phases of the project takes place. In the shift between phases there is a large risk that information and knowledge is lost. This could be looked at from an economical, project outcome, or best practice perspective.

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Appendix 4: Interview Protocol

Projektet:

- Omfattning (antal: lgh, kvm, tid)
- Kontraktsform?
- Vad har varit speciellt i detta projekt?

Personligt:

- Hur kom du till positionen du har nu?/ vad tycker du är mest intressant/roligast med den? Vad skulle du arbeta med annars?
- Varför har du valt denna branschen/vad tycker du är intressant med den?

Arbete:

- Vad är din roll?
    - Vilka arbetsuppgifter ser du som dina främsta?
    - Vad är din viktigaste uppgift vid överlämning mellan projektering och byggfas?
- Hur ser kommunikationen mellan projektering och byggfas ut i detta projekt?
    - Hur fungerar samarbetet mellan er?
    - Hur ofta har ni kontakt, i vilken form, (vad brukar det handla om? Eldsläckning?) både före och efter huvudhandlingars upprättande.
    - Vem är ansvarig för att kommunikationen?
    - Hur ser överlämningen ut mellan faserna?
- Hur deltar/påverkar du [triangelbild] bryggan mellan projektering och bygge?
- Hur ser kommunikationen ut mellan [triangelbild] projekteringsledare, projektchef och platschef?
    - Hur ser du på samarbetet er tre emellan?
    - Vilka kommunikationskanaler används?
    - I projektering?
    - I byggfas?
- Hur ofta träffar du "de andra två"?
    - Gör det någon skillnad för projektet hur mycket ni träffas/diskuterar?
    - Har någon ansvar för att sådana möten blir av? Vem?
- Har du medverkat I projekteringen? På vilket sätt? (platschef)
    - På vilket sätt har du påverkat utformningen av handlingarna? Vad vill du kunna påverka?
    - Hur har det hjälpt din förståelse över projektets utformning vid byggskedet?
- **Hur tror du att du skulle kunna göra för att förbättra kommunikationen och kunskapsöverföringen mellan Projektering och produktion? (personligt och generellt)**
- Hur tror du att din eller de andra två rollerna skulle kunna förändras för att få ett bättre resultat i projektering/överlämning?
- På vilket sätt säkerställer du att din kunskap från/inför ett projekt förs vidare?
    - Vilka åtgärder tas för att säkerställa att informationen kommit fram och blivit förstådd rätt?
- Hur utvärderas samarbetet i projektering/överlämning för att kunna bli bättre och effektivare i framtiden?

Appendix 5: Case Study Method

The five steps of case study research

Design

The study is conducted as a multiple-case case study, this in order to achieve a less vulnerable result, from an analytical standpoint. Single case studies are according to Yin (2009) most suitable when the case is either, a general representation of cases, or the unique environment of the case makes it rare. However, *"if you can do a two-case case study, your chances of doing a good case study will be better than using a single-case design."* (pp. 60-61). As mentioned, it is less vulnerable from an analytical standpoint, where, even with two cases, a direct comparison is possible. The number of cases chosen for this study was limited by the time-span of the study, where the assessment of the available time and resources concluded in the selection of 3 cases, which resulted in a total of 10 interviews with 8 interviewees whom all are employed in one out of the three positions studied.

To evaluate the design of the study Bryman (2011) identifies (1) Internal validity aimed to show the correlation between observations and theories, and (2) external validity, where the focus lies in generalization and externalization of the results to other venues or projects. However, Yin (2009) also adds (3) Construction validity to the theory. Construction validity is concerned with the operational measures, in other words, the choice of field, cases, and how they are approached. Further validation of study is found in chapter 4.2: Case Description

Reliability is in this study dealt with by choosing methods reliant on proven methods, thereby mitigating the researchers biases when interviewing subjects and analyzing the cases chosen for this study. A major part of the reliability is the method chapter containing and portraying the choices and methods with which the authors conducted this study. This could be used in order to replicate the results, or duplicate the study with altered variables.

Prepare

In preparation for the case study data collection, four steps were taken. These are supported by Yin -(2009) in his description of how to prepare to collect case study evidence (pp. 67-89) Firstly, reading up on how interviews are conducted. Consulting with individuals with prior knowledge in interviews and case study research. This revealed the importance of question formulation, that the subject feels secure during the interview, and the interviewers ability to steer the interview towards the desired topics. Secondly, a protocol containing the tropics to be discussed in the interviews was developed (appendix 4). The third step was to formulate interview questions for the topics defined in the protocol. These questions and their formulation is described further in the chapter 2.2.3: 'Collect data' below. Finally, primary interviews were held with two managers within the company. This was done in order to (1) identify additional cases, (2)find suitable subjects for the study, (3) gather information about, and affirm that the chosen research area within the company.

Collect data

The data collection method for the case study is; conducting interviews and gathering internal documentation describing the cases and processes used within these. To conduct interviews is *"One of the most important sources of case study information..."* (Yin, 2009, p. 106). It allows the interviewers to gain information of the studied cases, and the views of the interviewees. In this study the semi-structured interview method is used to conduct interviews. The open interview format allows for the interviewee to respond to questions from their point of view, often giving broader picture of the studied case than structured interviews, as well as limiting the interviewee to the studied field, in contrast to unstructured interviews (Bryman, 2011; Yin, 2009). The case study protocol and potential questions was developed to help the interviewers direct the interview towards the topics discussed. According to Yin (2009) there are five levels of questions, shown below. For the questions in the interviews, this study focuses on level 1 and 2 questions. This is because the study is interested in the interviewees' views and observations for the individual case and not their experience when relating to prior work. However, level 5 questions have occurred in the interviews, in order to verify the interviewees opinions, and to gather additional information regarding solutions.

1. Interviewee specific questions
2. Case related questions
3. Cross-case questions
4. Questions concerning the entire study, combining theory and cases
5. Questions regarding development, 'how should things be?'

The data collection occurred in three stages. First, interviews were held with DM1 and DM2 to validate the focus of the studied field, as well as further insight of the cases they represented. Through these interviews, information regarding the interviewees background and current role were covered. Identification of a third case was also a major aspect of the interviews, as well as an attempt on establishing trust. Interviewees were selected, currently in one of the three roles selected, within the three cases studied. Interviewees were selected, currently in one of the three roles selected, within the three cases studied.

Secondly, a set of questions were developed, through gathering open questions regarding the researched topic and the aim of the research questions. Questions were formulated as 'How'-questions instead of 'Why'-questions to create a less demanding and more open-ended and unbiased question with the goal being; creating a 'friendlier' environment, resulting in a higher relevance in answers (Yin, 2009). The framework for the questions were sent to the interviewees at least three days before the interview in order to create an understanding of the selected field of interest and to give the interviewees time to prepare, if so desired.

Lastly, interviews were held with all selected interviewees from March 14th – April 8th 2016. The interviews were conducted through the semi-structured framework described above. To save time, and create a flow in the discussion with the interviewee, all interviews were recorded, after approval from the interviewee. This allowed the interviewers to focus on the interviewees answers, to come up with better follow-up questions instead of writing most of the conversation down. Interviews were approximately 40 minutes, with SM1, -2, -3 as well as PM3 interviews held on site of the case study and remaining interviews held at the NCC office in Gothenburg, Sweden.

A limitation or risk when conducting interviews is that the interviewer and interviewees' perception of reality and the interpretation of information varies. This brings in to question the reliability of interviews in general. In order to counteract this risk, interview summations and direct quotes taken from interviews are emailed to the interviewees after the interviews and validation of information is received. A limitation for this study with regards to interviews is; the interview held with PM3 and SM3 was held in the presence of each other, perhaps limiting the answers of the interviewees. However, the tone of the interview was

relaxed, and the interviewers did not detect any tension between the interviewees during the meeting. The responses to the summations sent out should also reveal if the data obtained in this interview is conflicting with the interviewees opinion.

Analyzing Data

In preparation for the analysis, the recorded interviews were summarized and thereafter, answers categorized. Yin (2009) describes five techniques for analyzing data

1. Pattern matching, for comparing patterns found in empirical data with patterns identified in hypothesis.
2. Explanation building, for identifying probable causes without any significant patterns visible, through narrative reasoning and reflection of theory.
3. Time-series analysis, used to identify complex patterns where the chronological order of events also affects the pattern.
1. Logic models, identifying matches between staged events and empirical events.
2. Cross-case synthesis, used for identifying similarities in patterns between cases or case-groups.

The method chosen for analyzing the interviews is a combination of Explanation building and Cross-case synthesis in order to find; causality, patterns, and draw conclusions. The summaries of the interviews were analyzed in reference to (1) specific cases, (2) specific roles, and (3) between cases as a group. The summaries for the interviews were conducted in close time proximity to the interview. During the summation, notes were taken regarding the specific questions developed for the interviews, distinctive quotes were also written down, where a strong opinion or answer was given. The summaries were read through and compared to the interview recordings one more time before summaries were sent to the interviewee for validation.

Reporting Findings

This final stage, might be the most important. If the findings are not understood by, at least, the identified target group, the entire study has been a waste. This is dealt with by organizing the structure of the report in such a way, as to lead the reader through the theories used and cases investigated, in order for the reader be intrigued and understand the results and conclusions arrived at. This structure-method is described by Yin (2009) as 'theory-building structure', and is well fitted to exploratory case studies like this one due to that the logical structure of the report builds up the knowledge about theories, cases, and analysis culminating in the final conclusions and suggestions or further research. As the theory-building structure suggest, each chapter in this report is revealing new information, adding to prior chapters. The structure thereby builds the readers knowledge through the report to increase understanding of the research area and ultimately the conclusions reached.