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The Involvement of Purchasing in the Design Process

A Case Study at NCC Building Sweden

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

GABRIELLA JOSEFSSON
LOUISE LINDHE

DEPARTMENT OF ARCHITECTURE AND CIVIL ENGINEERING
DIVISION OF CONSTRUCTION MANAGEMENT

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Chalmers tekniska högskola, 2020

Department of Architecture and Civil Engineering
Division of Construction Management
Chalmers University of Technology
SE-412 96 Göteborg
Sweden
Telephone: + 46 (0)31-772 1000

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ABSTRACT

To succeed in a construction project, time, cost, and quality needs to be taken into consideration. Many projects currently overrun in both budget and time. To reduce this, collaboration and communication between the involved parties needs to be improved. Purchasing is handled as a separate process in the design phase. This causes lack in the collaboration between purchasing and the design team in the design process which must be addressed to improve the results of the project in terms of time, cost, and quality. In this study, purchasing involvement in the design phase was investigated on two of NCC's building projects, where the focus of the study is on the collaboration between the purchasing and design team during the design phase. In this study it was investigated how collaboration can be improved to produce better basis for purchases and construction documents. The study also examines how collaboration between purchasing and design is affected by increasing the involvement of purchasing in the work on digital models. The study was conducted through qualitative interviews on the two projects, where parallels and comparisons have been drawn from academic literature that exist on the topic.

The study has concluded that purchasing needs to be more involved in the design process, but for this to happen, an incentive must come from the company and its core processes. If there are no clear core processes that describe when and how purchasing should be involved in the design, there will be variation in the result from project to project since only past experiences can be drawn from. In the two investigated projects, purchasing had a large workload. This leads to unprioritized design meetings, where purchasing does not participate, in order to save in on resources. It has been discovered that instead of thinking primarily about resource efficiency, it is more effective to move towards a flow-efficient way of working. By having the purchasing team use BIM more, the team's workload will be reduced, and the time can instead be spent on collaboration which will improve the quality of the project.

Key words: Construction, Design Process, Partnering, Purchasing

Inköps involvering i projekteringsprocessen

En fallstudie på NCC Building Sweden

Examensarbete inom masterprogrammet Organisering och ledning i bygg- och fastighetssektorn

GABRIELLA JOSEFSSON

LOUISE LINDHE

Institutionen för Arkitektur och samhällsbyggnadsteknik
Avdelningen för Construction Management
Chalmers tekniska högskola

SAMMANFATTNING

För att lyckas med ett byggprojekt så behöver tid, kostnad och kvalité tas till hänsyn. I dagsläget överstiger många projekt i både tid och kostnad. För att minska detta behöver samarbetet och kommunikationen mellan de inblandade parterna bli bättre. Inköp hanteras ofta som en egen process under projekteringen. Det finns därmed brister i samarbetet mellan inköp och projekteringsteamet som måste underlättas för att förbättra resultatet på projektet med avseende på tid, kostnad och kvalité. I studien har inköps medverkan i projekteringen undersökts på två av NCC stora byggnadsprojekt, där fokuset har legat på samarbetet mellan inköp och projekteringsteamet i projekteringsfasen. Syftet med studien är att undersöka hur samarbetet kan förbättras för att producera bättre inköpsunderlag och bygghandlingar. Studien undersöker även hur samarbetet mellan inköp och projekteringen påverkas genom att involvera inköp mer i arbetet kring BIM. Studien har genomförts genom kvalitativa intervjuer på de två projekten, där paralleller och jämförelser har dragits till den akademiska litteraturen som funnits sen tidigare.

Studien visar på att inköp behöver vara mer involverad i projekteringen, men för att detta ska ske behöver ett incitament komma från företaget och dess kärnprocesser. Finns det inga tydliga kärnprocesser som beskriver när och hur inköp ska vara involverade i projekteringen så kommer det, från projekt till projekt, bli stor variation av resultatet då arbetet blir baserat på tidigare erfarenheter. I de två undersökta projekten så har inköp haft en stor arbetsbelastning, vilket har gjort att projekteringsmöten där alla inblandade i projektet ska delta har blivit bortprioriterade för att spara in på resurser. Något som tas upp i studien är att istället för att i första hand tänka resurseffektivt, börja gå mot ett flödeseffektivt arbetssätt. Detta för att fokusera på aktiviteter som skapar värde för kunden. Genom att använda BIM mer i inköp kommer inköparnas arbetsbelastning att minska och tiden kan istället läggas på en ökad involvering med resten av projektmedlemmarna för att förbättra kvalitén på projektet.

Nyckelord: Inköp, Konstruktion, Projektering, Samverkan

Contents

Preface

This master thesis has during the spring 2020 been developed as the end work of a five year civil engineering education. The thesis constitutes as a basis for a master's degree examination in Design and Construction Project Management at Chalmers University of Technology.

First, we would like to thank our supervisor, Janni Tjell at NCC and Chalmers University, for your help and guidance through this thesis. She has been a support during the whole work and provided us with input from the company. We would also like to thank all interviewees for your contribution which helped us with developing the knowledge on the topic, but also made it possible for us to conduct a case study. We would also like to thank our examiner Mattias Roupé at Chalmers University of Technology for helping us during the thesis. We are grateful for the welcoming help you gave us.

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Göteborg, June 2020

Gabriella Josefsson
Louise Lindhe

Notations

AEC *Architecture, Engineering, Construction*

BIM *Building Information Modelling*

DB *Design-Build*

DBB *Design-Bid-Build*

LOD *Level of Detail or Level of Development*

PDSA *Plan, Do, Study, Act*

PIP *Design, Purchasing and Production*

POP *Product, Organization and Process*

VDC *Virtual Design and Construction*

1 Introduction

This chapter is an introduction to the thesis. An understanding of the background to the topic will be presented. Then the purpose of the thesis and the research questions that will be answered in the thesis will be defined. Finally, the delimitations of the thesis will be presented.

1.1 Background

Managing construction projects is a demanding task that requires exchange of knowledge and information between the involved disciplines for the project to succeed (Ottosson, 2009). The success of a construction project depends on the balance between cost, time, and quality (Atkinson, 1999), and overruns in both time and cost are common problems within the AEC industry (Hussin et al., 2013). According to a survey done by Svensk byggtjänst (2014), two major factors why Swedish construction projects exceed in cost are deficiencies during the planning and designing, and lack of information sharing among the parties involved. Project members not receiving the same information is a common problem linked to the lack of information sharing that is leading to increased costs. Documentation that is both insufficient and inexplicit is also a significant reason. By obtaining more effective communication, where relevant information is shared among the project parties, the chance of keeping the schedule increases and the risk of interruptions decreases. The profitability for the involved parties will also have a positive influence of more effective communication in the AEC industry. Furthermore, moving towards a more digital construction industry can have positive effects on the cost, time, and quality for the project (Aghimien et al., 2018), and using Building Information Modeling (BIM) technology is one way to increase the integration between the projects members (Azhar, 2011).

Purchasing is a process that often is separated and managed parallel to the design and production process. Furthermore, the dependency of subcontractors and suppliers for contractors is increasing and is becoming more and more important for the overall result of a construction project (Bemelmans et al., 2013). Thus, the work of a purchaser has an important role on the outcome of the project costs, and according to NCC (2019) purchases represent approximate 75% of the total cost in a construction project. How to manage the purchases is thereby crucial for the outcome of the total project costs.

Effective communication among the project team and the outcome of the project's purchases are both considered as influencing factors of a project total cost. Still, it was shown in a lean construction workshop with design managers at NCC that there is a lack of communication and integration between purchasing and the design team (NCC, 2019c). In present, a well-defined standardized process regarding how the purchaser and design manager shall share information and collaborate does not exist. Further on, design managers experience that these two departments have a lack of knowledge regarding each other's tasks during the different stages of the design process.

1.2 Purpose

The purpose of this master's thesis is to analyse the integration between the purchasing, and design team at NCC and which opportunities and challenges there are by involving purchasing more in the design phase. The focus in the thesis is to depict the current

relation between purchasing and the design team, and to create an understanding of how this collaboration influences the quality of the produced design documents. Furthermore, the purpose is to investigate how the involvement of purchasing would be affected by using BIM more in purchasing.

1.3 Research Questions

In this thesis the following research questions will be answered and discussed:

- How is purchasing integrated in the current design phase in construction projects?
- How can more involvement of purchasing in the design phase affect the project and which opportunities and challenges are there?
- How will the involvement of purchasing in the design phase be affected by utilizing BIM more?

1.4 Delimitations

This thesis is limited to only review the collaboration problems between purchasing and design team in the design phase. The thesis will only manage these two departments and will not cover the entire construction process and its participants. When using the term purchases in the thesis, it includes both purchasing of material and consultants. The case study treats NCC as a representative for the AEC industry, while the literature review will be generalized for the whole AEC industry. The literature review is limited to only describe the topics that the research questions address. Literature that is not relevant for the subject matter will not be presented. Two projects at NCC were chosen and examined in parallel to each other and were located in Gothenburg. Both projects are within the building department and are classified as large projects. The case study was also limited in only looking into partnering projects (in Swedish “samverkan”) where a Design-Build project delivery was used. Furthermore, the professions of the interviewees were limited to roles linked to purchase and design. Consequently, all people involved in the projects were not taken into consideration in this study.

2 Methodology

The aim of this chapter is to describe the methodology for conducting this thesis and how the thesis was structured. In this chapter, research approach, research design, ethics, and quality analysis of research method will be discussed. The research design is divided into two subsections, literature review and interviews.

2.1 Research Approach

The method of this master's thesis is based on qualitative research opposed to a quantitative research, meaning that the basis for the research is on descriptive data other than numerous data (Taylor et al., 2015). Qualitative research is about the social world and the interpretation of it (Bryman & Bell, 2015). The direction of the outcome in this type of research is affected by the studied objects and their perspectives on what is important. In qualitative research, theory and research is related with an inductive approach. This means that the outcome of the research is a theory which has evolved from empirical findings where generalized conclusions have been made. An inductive approach allows the researcher to be more flexible in the data collection and to be unbiased with the direction the research leads. A qualitative research with its inductive approach was therefore suitable for this thesis that aims to understand the communication problems within an organization and create conclusions on how to improve it.

2.2 Research Design

The strategy method for this thesis is an embedded two case study combined with a literature review. A two case study was chosen to see how NCC operates and to make a more generalized conclusion about the AEC industry. A case study on multiple cases was not chosen because of the time constraints for the master's thesis. If multiple cases were chosen, the depth of each case would have been poor. Yin (2009) states that multiple case studies have its disadvantages through its resource intensiveness, but a multiple case study increases the reliability of the findings. Two cases were chosen to have a comparison and to be able to deeply investigate each case.

The design of this thesis is built upon five important components that are stated by Yin (2009): research question, the units of analysis, analysing the data, and interpreting its findings. According to Yin (2009) a case study is appropriated for "*how*" or "*why*" questions. These types of questions have an explanatory nature and are good when phenomena within a real-life context are investigated. After the research questions were designed for the thesis, the case study method was considered appropriate to answer the research questions raised. The case study can be seen as an embedded case study, where the unit of analysis of the thesis is NCC and the two projects of the company were chosen as different sub-units of analysis (Yin, 2009). An embedded case study is suitable for descriptive case studies and examining some chosen aspects of the case. Compared to a holistic case study where the whole case is examined. With a qualitative approach to the thesis, the data was collected from a literature review, interviews, and internal documents from NCC, to be able to answer the research questions. By using different sources of data, triangulation has been adapted to validate the data. A method on how the collected data should be analysed was made when the method was designed. Yin (2009) states that one thing that should be considered when designing the study is to have a general analytic strategy, as to not delay the thesis when the data is collected. Both analysing the data and interpreting its findings are done to make sense of the collected data.

In an early stage of the thesis, a literature review was done to critically collect data from previous research projects. This was done to get an overview of the problem. The literature review was constantly improved over the course of the thesis (Fellows & Liu, 2015). Interviewing eleven professionals as a qualitative research is a way to understand the problem from an interviewed persons point of view instead of an objective angle (Brinkmann & Kvale, 2015). How literature review and interviews were completed are described in the following two sub-chapters.

2.2.1 Literature Review

A literature review is done in research to increase knowledge of what is already known within the investigated area, what concepts that have been used in previous studies, and if there are any inconsistencies within the topic (Bryman & Bell, 2015). The literature review was performed from the start of the thesis in order to increase the understanding and knowledge of the subject before the interviewing process. The literature review was then continuously processed throughout the whole period to fit within the area of the empirical findings. Theoretical data regarding the construction process, visual management, lean management, cost management, and digitalization was obtained mainly from books, e-books, reports, and journal articles. The search for academic sources was primarily made through Chalmers Library and the database Google Scholar. For finding adequate literature for the topic, keywords such as purchasing, lean construction, design process, VDC, collaboration, and construction were used. The literature was then evaluated objectively and different sources within the same topic were processed to increase the reliability and gain a broader perspective.

2.2.2 Interviews

For executing an interview study, Brinkmann and Kvale (2015) presents a seven stage guideline on how to proceed, which was followed in this thesis. These seven stages are thematizing, designing, interviewing, transcribing, analysing, verifying, and reporting. Hence, the interview study initiated with formulation of the purpose of doing the interviews, i.e. thematizing of the interviews. The research questions and the literature review were therefore performed before designing the interviews, although these sections were edited later on in the thesis work. When designing the interview study, all the following stages were taken into consideration to ensure that the design matched the purpose of the study. The interviews study contained nine interviewees at two of NCC's building projects. Five interviews at each project were completed, where the fire consultant was the same person in both projects. The interviewees were chosen due to their profession so that equal roles were interviewed at each project. This enables comparison between the findings. The professions were design manager, project purchaser, project manager, fire consultant, VDC-manager and VDC-coordinator. In addition to the nine interviews at the examined projects, two more interviews were conducted with central resources at NCC to obtain a more general and objective angle of the topic. The roles of the central resources were leading technical specialist and head of design and installation control. Thus, eleven interviews have been made in total and are shown in table 1 below.

Table 1. Interviewees' profession and related project.

Profession	Project
Design manager	Masthuggskajen
Project purchaser	Masthuggskajen
VDC-coordinator	Masthuggskajen
Project manager	Masthuggskajen
Fire consultant	Masthuggskajen and Liseberg
Design manager	Liseberg
Project purchase 1	Liseberg
Project purchaser 2	Liseberg
VDC-manager	Liseberg
Leading technical specialist	Central resource at NCC
Head of design and installation control	Central resource at NCC

The interviews were semi-structured meaning that general and open-ending questions was mainly asked (Bryman & Bell, 2015). Semi-structured interviews are a flexible structure which enables for follow-up questions that can deeply explore the thoughts of the interviewee that is of interest for the study. The interview questions were formulated in a guide where the main part of the questions was the same for all respondents, but some complementing questions were added to fit the specific profession. The interview guide is attached as appendix 1. The interviews were approximately 45 minutes long. No notes were taken during the interview, instead audio recording was used to enable transcription of the interviews afterwards. When all interviews were finalized the analysis of the collected data was initiated. The main approach for analysing was categorizing by interview question and comparison of the responses. The next of the seven stages presented by Brinkmann and Kvale (2015) is verifying, which means to determine the quality of the findings in terms of validity, reliability, and generalization. This is further discussed for the method as a whole in section 2.4. The findings of the interviews were then compiled by each project and were divided into the main topics: *Collaboration*, *Costs*, and *Use of BIM*, which is presented in section 4.2 and 4.3.

2.3 Ethics

Brinkmann and Kvale (2015) states that tension can be created in a qualitative research between the knowledge obtained and the ethical concerns. The ethical concerns were therefore regarded throughout the whole process of the thesis from the start until the final report. The authors of this thesis have not had any connection to the company before and could therefore be objective in the analysis and not produce a biased result. The ethical concerns have been taken into consideration when going through all the seven stages of the guideline, described in section 2.2.2, when conducting the interviews. Before the interviews the interviewees were informed about the purpose of the thesis, so the interviewees had knowledge about what the collected data was going to be used for. An approval to record the interview was permitted by the participants before the interviews started to protect their integrity. After the interviews were done all participants got the opportunity to read through and approve what the authors wrote, which was done to prevent misunderstandings and to prevent any harm or deception (Yin, 2009). To make the interviewees anonymous, names were left out of the thesis, only profession and project was presented.

Respect and justice are according to National Research Council (2003) two principles that should be considered when doing research on humans. This research is not on the humans themselves, but a substantial part of the data collected is based on interviewee´s thoughts and experience, and the interviewee´s privacy should be treated with respect. Participants in a case study are vulnerable and it is important to respect this. This was considered during the interview process to retain the privacy and confidentiality of the interviewees. If the participant in any case felt uncomfortable the participant had the availability to pull out of the study. Yin (2009) states that to avoid the result becoming biased, it is important to be honest, avoiding deception, and accepting responsibility. It is important to make justice when choosing the research participants of the study, that no one is excluded (National Research Council, 2003). Consequently, the participants were chosen with care to fill out both the design team and purchasing perspectives of the topic.

2.4 Quality Analysis of Research Method

To analyse the quality of the research method, reliability and validity are taken into consideration. Reliability means that the study can be performed again and achieve the same result (Yin, 2009). In other words, the data collecting procedures should be designed and documented in a way that someone else can follow the same procedure and get the same findings. To increase the reliability of the case study, documentation such as an interview guide was used, see appendix 1. The reliability of the literature review was considered by analysing multiple academic sources within the subjects to ensure that the collected data was correct.

Yin (2009) discusses two types of validity of relevance for this research to consider when performing a case study, and those are construct and external validity. To achieve construct validity during the data collection, multiple sources should be used and a chain of evidence should be established. Multiple sources were used in the research by collecting data from both interviews, literature review, and internal documents. These sources have been analysed together to reach the conclusions of the thesis. For the literature review, multiple academic sources which are still relevant were chosen in order to increase the validity. Furthermore, two projects were investigated for the case study, and for each project multiple interviews were made to obtain different point of views and a variety in the data. The chain of evidence has been the basis of forming the report so that each chapter is connected to the other chapters, and the reader should therefore be able to follow the evidence process from the conclusions backwards. At the end of the research all interviewees were provided with the result of the case study and approved the presented data. External validity means the extent to which the findings of the study can be used in a general context (Yin, 2009). One case study tactic is to form the research design with a theory section, which is used in this research to reach more generalized conclusions.

3 Literature Review

This chapter aims to present a review of processes, definitions and theories in the areas of the construction process, visual management, lean management, cost management, and digitalization.

3.1 The Construction Process

Construction projects can be large or small, but the same process needs to be reviewed in order to establish a building, see figure 1. The construction process initiates with the need for a new building or a reconstruction of an already existing building (Nordstrand, 2000). When there is a need, the client establishes the desires and requirements for the future building. The project starts with the determination of how the building should be constructed. This means decisions regarding technical systems, materials, and design solutions for instance. This phase, i.e. the design phase, is the part of the construction process most relevant for this thesis and is therefore further clarified in section 3.1.1 below. The outputs from the design phase are various construction documents such as drawings, descriptions and models, which are the basis for the next step in the process, the construction phase (Bynum et al., 2013; Nordstrand, 2000). Although, depending on the type of contract for the project, the final part of the design phase and the construction phase can be performed in parallel if the project is of a Design-Build (DB) type (Nikou Goftar et al., 2014). This is in comparison to a traditional Design-Bid-Build (DBB) contract. When the construction is completed and the building is operational, the last and longest step commences, which is the management of the building (Nordstrand, 2000).

Figure 1: Phases in construction projects.

3.1.1 The Design Phase

The design phase of a construction project can be divided into three stages, see figure 2, where the first one is the conceptual design (Nordstrand, 2000). Several sketches of different design options are developed in this stage, but the aim is to choose one main proposal of the construction in the end of the conceptual design. This is presented by proposal drawings which are used as a basis for the next stage during the design process, which is the schematic design. The purpose of the schematic design is to design the different technical systems to meet all the requirements. During this stage, project planning documents are developed. The final stage is the detailed design which is the development of building documents. Detailed design is the most extensive stage during the design phase and is the stage where all final dimensions are set.

Figure 2: The three stages of the design phase.

Construction projects are often complex which imply that many disciplines need to cooperate during the design phase (Gray & Hughes, 2001). Several roles are involved during the design phase. The design team consist of architects and engineering disciplines which are involved during the whole design process. Specialist contractors may also be a part of the design process and are in that case mainly involved during the latter part of the design phase. To coordinate all participants, the design manager has the overall responsibility over the design phase and will make sure that the design is within the requirements as well as delivered on time.

3.1.2 Design-Build Project Delivery

Construction projects can either be Design-Build (DB) or the traditional Design-Bid-Build (DBB) type of project delivery. The main difference between DB and DBB is when in the construction process the contractor is chosen and its participation in the design phase (Nikou Goftar et al., 2014). Due to the delimitation of only investigating DB projects in this thesis, DBB project delivery will not be further developed and explained. DB on the other hand, is a flexible project delivery form since the design does not need to be complete before the construction starts. This overlapping of the detailed design and construction will thereby result in overall time savings of the project.

In a DB project the client only has one contract and it is with the contractor (Nikou Goftar et al., 2014). The contractor thereunder has its own contracts with the other parties involved in the project such as architects, consultants, and subcontractors. When using DB project delivery, the client hands over the responsibility to one single part, the contractor, who will be responsible for both the design and construction of the building (Öztaş & Ökmen, 2004). An increased risk is thereby transferred from the client to the contractor. The single contract also means saving in time and cost when not needing to select another general contractor for the construction phase when the design is completed (Stutz, 2000). The design team is put together by the DB contractor and is work closely together creating a stronger relationship among the team (Stutz, 2000; Tenah, 2000). Since the DB contractor has the single responsibility for both the design and construction it is therefore more likely that the project members will work in the project from the beginning to the end. The team can thus increase the possibility of securing the quality of the project. The early involvement of the contractor also implies that the contractor can provide input to the design earlier in the project (Nikou Goftar et al., 2014). This means increased opportunities to design more cost-effective solutions (Tenah, 2000).

3.1.3 Partnering in Construction Projects

Partnering (in Swedish “samverkan”) has been developed in the construction industry over the past years to create closer relationships among the project’s parties (Black et al.,

2000; Byggherrarna, n.d.; Chan et al., 2004). A partnering agreement is set up between two parties, either between the client and the contractor or between the contractor and its subcontractors (Black et al., 2000). The tradition in the AEC industry is having conflicting relationships between the actors and the aim by using partnering is to move away from this, which is one of the main arguments. One characteristic of partnering is the work towards shared goals to create a win-win situation between the parties, and not only sharing gains, partnering also implies risk sharing. This creates a project organization with more open communication, increased trust, and more efficient problem solving and teamwork among the parties (Chan et al., 2004). The fact that all participants strive to achieve the same target, increases the mutual understanding within the project organization (Black et al., 2000).

3.2 Visual Management

The construction design team consists of multidisciplinary groups, which increases the organizational complexity and therefore also the challenges regarding collaboration and sharing information (Gray & Hughes, 2001). To enable and facilitate cross functional collaboration within a design team it is important to establish transparency in regard to knowledge and information sharing. In that way, conflicts can be solved and the result will meet the requirements from the client. Gray and Hughes (2001) states that an effective way of integrating the team is that all participants communicate the information to each other, instead of reporting to the design manager. A system that can help integrate the design team and facilitate the communication is by applying visual management. Visual management is a management system that focuses on increasing the understanding of information by stimulating multiple senses (Tezel et al., 2009). By using a visual environment, new ways of sharing information are being discovered. Ways to enhance the coordination, communication and collaboration among the team members in a construction project can be done with structed work methods based on visual management such as Big Room (Temel et al., 2019). Big room brings multiple stakeholders together in a decision-making process where data and documents are approachable to everyone. This is done by working together in a large room which improves team performance, accelerates decision making, and reduces project costs by achieving better communication. When using visual management among the design team, the team is not as dependent on the design manager in the daily work (Tjell & Bosch-Sijtsema, 2015). Furthermore, commitment from the actors and a collocated working environment are two important aspects needed to succeed with a more self-sufficient design team. The combination of visual management and available visual tools can support the knowledge and information sharing process between the involved parties in the design team. This provides the right quality at the right time. In the following sections the collaboration in the design phase, knowledge sharing, and information sharing will be further discussed.

3.2.1 Collaboration in the Design Phase

To initially define the term collaboration, it is the work of a group that is jointly working towards achieving the same goals, which they would not be able to reach individually (Chiu, 2002). The design process is a creative and innovative process that by collaboration between the design members support the problem solving (Girard & Robin, 2006). From a social aspect of collaboration, teamwork plays an important and crucial role on the success in the design process (Lang et al., 2002). Teamwork is developed by creating

settings where face to face communication can occur. This enables the design members to gather around a drawing or model during discussions using body language and gestures when communicating. As projects get larger, the more critical the collaboration and communication among the involved becomes (Chiu, 2002). Information then needs to be communicated throughout a bigger organization and by several team members which requires good management and coordination.

By the work of Thompson (2003), internal interdependencies of workflows in an organization are presented, for instance sequential and reciprocal interdependences. Bølviken et al. (2010) describes the management of the design process linked to Thompson's (2003) interdependencies by three different phases of the design: the creation, the production, and the decision making. During the creation process, where the idea of the design is developed, the main interdependency is the reciprocal. This means that the outputs from all parties become inputs to the other parties of the project and the coordination of work at this phase is thereon primary based on mutual adjustments and dialogues. The production process is where the design is prepared in shape of drawings, models, and documentation. Sequential interdependencies are dominant in this phase meaning that the coordination is based on collaborative planning and schemes. In order to complete one task, another work must be done prior. In the decision process of the design, where the final decision of what to be constructed is made, the strategy of management is a combination of both reciprocal- and sequential interdependencies. Thus, the process is based on both mutual adjustments and dialogues, but also on collaborative planning and schemes.

3.2.2 **Knowledge Sharing**

In construction projects highly skilled individuals and competent design teams, suppliers, and constructors are needed. According to Newell (2009), a lot of organizational work takes place in projects in relation to knowledge work, where the focus is innovation. By bringing together individuals from different disciplines the knowledge can be shared. It is therefore of high importance that the involved disciplines trust each other as well as having mutual personal and professional respect. In the design process it is of importance that the interaction between different participants in the projects occur successfully, where internal and external factors can affect this interaction (Bosch-Sijtsema & Henriksson, 2014a). The knowledge that is being shared can be of different types, it can be explicit, tacit (Nonaka, 1994) or embedded knowledge (Bosch-Sijtsema & Henriksson, 2014b). Knowledge that is transmittable in formal, systematic language is called the explicit knowledge (Nonaka, 1994). Explicit knowledge is knowledge that is easy to talk about and easy for others to learn (Clegg et al., 2016a). While, tacit is rooted in commitment, action and involvement in a specific context (Nonaka, 1994). The tacit knowledge makes it hard to formalize and communicate due to the personal quality. An example of tacit knowledge is how to ride a bike, you know how it is done but the knowledge is hard to transfer (Clegg et al., 2016b). In the design phase of projects, the tacit knowledge is central to the creativity required of innovative projects (Egbu & Robinson, 2005). To get the most out of tacit knowledge it should be made during face to face interaction or through project work (Nonaka, 1994). Embedded knowledge is knowledge locked in products, culture, processes, routines or structures and is difficult to share when complex projects are performed by multiple organizations and disciplines (Bosch-Sijtsema & Henriksson, 2014b). Embedded knowledge can be facilitated with use of visual communication. The use of visual communication creates innovation in

technology and development of work practices and will in turn support the interactions. By using Building Information Modeling (BIM) as visual communication will increase the collaboration and communication among the involved parties.

It is often problematic to share knowledge across projects (Newell, 2009). Cross-project learning is often done at the end of the project or the end of a milestone, to get a feedback of the work that is made. When a project or milestone is finished the problems that have come up are documented in a database. Other projects can then search in this database and learn from previous mistakes. However, the responses that this cross-project sharing has facilitated have not been good. This is because every project has a time limit and it takes time to search in the database (Newell, 2009). There are five different mechanisms that Newell (2009) takes up to facilitate this problem. The first is belief in uniqueness of context, where every project is unique, but when breaking the project down, there are always some parts that will be the same as another project. These parts can be shared across the organization. The second one is standardization, where some projects are not as unique and are therefore seen as a standard. In these situations, knowledge sharing is restricted, and when a slight uniqueness in the project arises, the standardization will become an inhibitor to the successfulness of the project. The third one is the ability to capture and access softer lessons, where it is difficult to share what is actually learned. As the example Newell (2009) provides, a project experienced problem dealing with an external consultant because they failed to specify the requirements. The lesson learned about this process did not get shared. The fourth one is project reviews and milestones, which is not effective because there is often a lack of time between the finishing of projects and the review of the project. People have moved on from the project and are not interested in spending time reviewing the project. The last one is the lack of awareness that knowledge transfer is needed. People only search for help when a problem is noticeable. This arises because people are ignorant to the knowledge that is not possessed.

3.2.3 Information Sharing

The management of the design process aims to create a collaborative working environment among the design team members (C. Gray & Hughes, 2001). This refers to the importance of continuous communication, interactions, and information sharing to increase the knowledge transfer within the team. Design problem-solving is dependent on information sharing from different sources to be able to evaluate solutions. Hence, it is important that information reach the participants. The construction industry is project-based which implies the creation of temporary workgroups within and between organizations (Collinge et al., 2009). Consequently, there are many actors that both create, receive, share, and manage amounts of different information. Collinge et al. (2009) further claims that there is often insufficient knowledge regarding what information is required for the upcoming stages of the project process. The design phase is dependent on communication among the team and although it is becoming more common to use Building Information Modelling (BIM) for information management, there is still the human aspect of creating and interpreting information that is shared (Emmitt, 2014).

To define the word information, data becomes information when it is delivered in a form that is usable for the receiver (Emmitt, 2014). This means that it is important that the information is of value which depends mainly on three aspects: accuracy, timing, and appropriateness. The user of the information is crucial when discussing its value, and it

depends on who the receiver is and how the receiver interprets the information at different times. To ensure that information is of value for the receiver, Emmitt (2014) stated six rules to follow when designing, i.e. preparing information. These rules are clarity and brevity, accuracy, consistency, avoiding repetition, redundancy, and checking. Clarity and brevity mean that the information should be clear and concise. Accuracy means documentation should be specific and complete. Further on, dimensions and notations need to be used in a consistent way in the project's documentation. By avoiding information repetition in various documents, confusion can be minimized, and unnecessary resources can be saved. The redundancy rule refers to the risks of getting redundant information if information and documentations from earlier project are being used as a basis. Finally, information should always be checked before sharing it with others.

Tribelsky and Sacks (2011) state some types of waste that can be identified from having an inefficient information flow during the construction design process. Firstly, one source of waste is when outdated versions from other designers has been used as a basis for a continued design. Thus, the information has not reached the person in need, who consequently may have to redo the work performed on inaccurate information. Another waste recognised in the design process is waiting on accessing information needed to continue working on the specific project. Consequences of this waste are that a shift of focus to another project occur instead, and unnecessarily time will be spent on shifting between different projects and thus will need start-up time to be reminded of the project and the work earlier left behind. A third waste presented by Tribelsky and Sacks (2011) is over-designing, meaning that designers tend to design more than needed hoping that it will not be necessary to add or change information later in the project.

3.3 Lean Management

In the late 1940's a revolution in the Japanese's manufacturing techniques started to evolve (Gann, 1996). It started out with experiments in Toyota that resulted in a new approach. This approach will later be called lean production where the traditional mass production transformed into a more efficient system. Where less of everything was used, less material, smaller manufacturing store places, less labour, etc. In 1992, Koskela came out with an article describing how lean production can be adopted into the construction industry (Koskela, 1992). The focus in lean construction is transformation, value and flow. Where the point is to generate an input in a process and reducing all the activities that do not add any value to the project (Koskela, 2000). The output must then meet the demands of the customers.

A system that is used in the lean philosophy and adapted to construction projects is Lean Project Delivery System, LPDS (Koskela et al., 2002). LPDS attempts to create an efficient way to design and produce projects in the AEC industry. LPDS is a controlled, structured, and improved delivery method to achieve all three focuses in lean: transformation, value and flow. In LPDS, as can been seen in figure 3, each phase of the construction project is connected to the need of the overlapping triangles. For instance, in the Lean Design phases, which has the job of generating and aligning design concepts, design processes, and production design together. These three elements influence each other which will create conversations among the various stakeholders. Ballard (2000), states that it is important to align the three elements in the triangle. When this is done the next phase can

start. The LPDS delivery system will result in better and different understanding of the involved disciplines (Koskela et al., 2002).

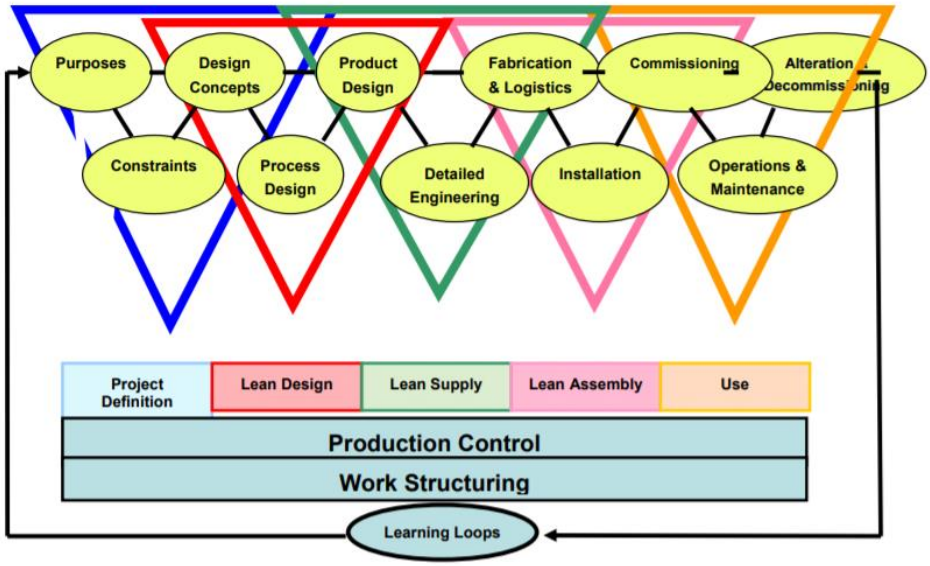

Figure 3: Lean Project Delivery System (Ballard, 2008).

3.3.1 The Efficiency Paradox

Lean is an effective management system where the focus is on keeping it simple (Dibia & Onuh, 2010). In the lean philosophy, resource effectiveness is highlighted, where the focus is on how the organization is utilizing resources (Koskela, 1997). In resource efficiency the resources should be fully utilized (Modig & Åhlström, 2012). From a cost perspective, this endeavor to always utilize resources fully is an effective action. The driving factor for resource effectiveness is measuring when the employees create maximum value for the project, with as little effort as possible. To be effective with resources is something that is common in the AEC industry and something that the industry often strives to achieve (Modig & Åhlström, 2012). The continual ambition to make each discipline work as effectively as possible will create an organization with sub-optimizations. Sub-optimizations are when a system or process does not give the best possible output because optimization in activity can lower the degree of optimization in another activity (Beenhakker, 1964). This can arise because the coordination between the different resources is not good, which produces a lack of information. Further on, sub-optimizations create extra work for the employees and these activities do not create any value for the end product (Modig & Åhlström, 2012). Therefore, sub-optimizations will decrease the efficiency in the flow of the whole construction project. This highlights the efficiency paradox, where an intensive focus on resources effectiveness will affect the flow efficiency negatively. The solution to this paradox is to first focus on the effectiveness in the flow, where flow is the process where either material, information, or people's experiences are being processed. Effectiveness in flow looks at the whole process and attempts to make the process as short and effective as possible. According to Modig and Åhlström (2012) lean is a strategy to manage this paradox where flow efficiency is prioritized by always defining value from a customer's perspective.

Modig and Åhlström (2015) points out three important laws of processes that are affecting the flow efficiency, which is Little's law, the law of bottlenecks, and the law on the effect of variation on the process. Little's law says that the throughput time increases the more flow units there are being processed and the longer the cycle time is. The throughput time is defined as the product of the flow units in work multiplied by the cycle time. The cycle time is the time it takes for an input to go through a process and to become an output, this material or information can then be passed on to the next process. The law of bottlenecks says that where bottlenecks arises in a process the throughput time increases. Before a bottlenecked, a queue of material, information, or humans often arises where a waiting time accumulates because the work cannot be handled when it comes to that process. Even if queues of information are hard to see it is often there. The law on the effect of variation on the process says that the throughput time increases exponentially the higher variance there is in the processes and the closer the utilization of recourses is to 100%. These three laws of processes are showing that the more focus there is on resource efficiency, the higher the risk of the flow suffering. To eliminate those risks Modig and Åhlström (2015) takes up four important parts to think about, which is to eliminate queues of material, information and humans, decrease the cycle time, add more resources which will increase the capacity and reduce the cycle time, and try to eliminate different types of variations in a process.

3.3.2 Pull-Planning

Pull-planning comes from the lean philosophy where push and pull is compared (Koskela, 1999). This is a way of controlling the movement of material in the production system. A pull-system is coming from a need while push is pushing in as much information as possible, that are thought to be needed. Pull-planning is a planning tool to use during the design process to obtain more effective collaboration among the design participants (Fosse & Ballard, 2016). This means that the planning is done backwards and is based on the project's milestones (Tiwari & Sarathy, 2012). In pull-planning, all disciplines' work is mapped together in the schedule based on deliveries needed for each discipline. This can be done by simple post-its where one post-it symbolizes a delivery that is needed, for instance a drawing or a decision (Fosse & Ballard, 2016). To successfully use pull-planning it requires the involvement of all project members to update their tasks since if one task deviates it will push all the other tasks as well (Tiwari & Sarathy, 2012).

Using pull-planning as a planning tool promotes an effective collaboration between the design team members (Fosse & Ballard, 2016; Tiwari & Sarathy, 2012). Namely, the relations, trust, and communication among the members are strengthened (Tiwari & Sarathy, 2012). A study conducted by Fosse and Ballard (2016) showed that pull-planning means significant benefits of the transparency, reliability, and commitments in the design team. By having a transparent planning process the understanding of the other members increases. It is also easier to determine the interdependencies and constraints in the team.

3.3.3 Model for Improvement

The word kaizen comes from the Japanese language, meaning continuous improvement (Salem et al., 2006). In the lean philosophy, kaizen is an important practice. By using qualitative cycle opportunities, workers have everything that is needed to actively participate in the process of improving their work. One quality cycle is PDSA that has its roots in scientific method and the philosophy of science that was developed over 400

years ago by Galileo (Moen & Norman, 2006). In 1939, the Shewhart cycle was introduced, where the thinking of Gelileo was developed (Moen & Norman, 2006). Instead of thinking design, produce, and rethink, as a timeline a circular timeline was created. Further on, Deming improved the cycle that in 1993 got the name PDSA, which stands for Plan, Do, Study, and Act and is a continual cycle. The PDSA cycle is used to continually give feedback and improve the work (Moen & Norman, 2006; Salem et al., 2006). The first step in the cycle is plan, where the elimination of unnecessary work is done. The second step is do, where the working method is applied. The next step is study, where the results of the applied working method are measured. The last step is act, where it must be determined whether the changes should be applied as a standard, or the process should go through the cycle again. According to LIU and CAI (2016), when the PDSA cycle is established in a large construction project, it is a good method to control the costs of the project. In the preparation phase, the PDSA cycle can guide the project to make the cost control plan. Furthermore, the model has been developed where three questions are applied that defines the aim, measures and possible changes and is called Model for Improvement, see figure 4 (Moen & Norman, 2006).

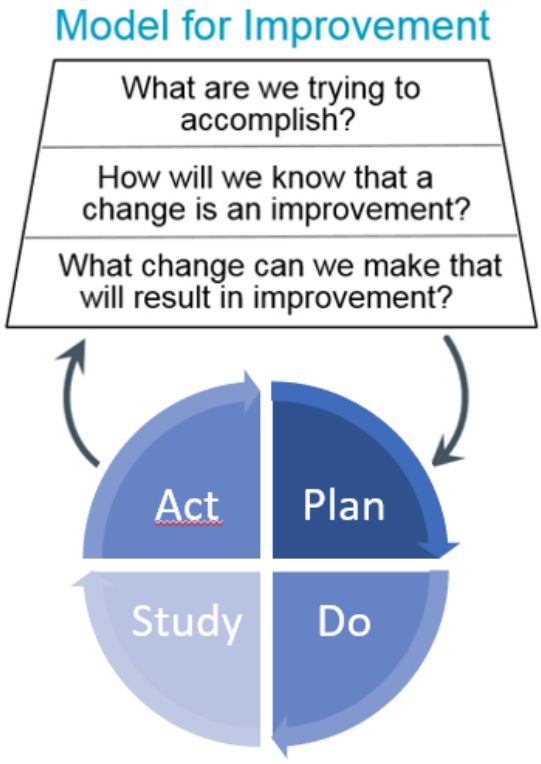

Figure 4: The Model for Improvement cycle (Moen & Norman, 2006).

3.4 Cost Management

The cost of a project is the sum of all costs during the construction process, both indirect and direct costs (Zhang & Zhuang, 2014). The indirect costs are the costs of construction companies for the preparations and the on-site management. In other words, all the administrative costs. The direct costs are the costs that create value for the building. When adding the indirect and direct costs together with the profit that the contractor wants to make, it becomes the results in the total price for the product or service (Granja et al., 2005). A cost management system uses inputs and processes to satisfy management objectives when producing outputs for internal users information (Hansen et al., 2007). This system provides information from the costing of products and services, planning and controlling, and decision making. Typically, cost management has been insufficient, which Hansen et al., (2007) notes, that there is a difference between designing to a cost and costing a design. Ballard (2006) mentions that the costs in AEC industry have traditionally been managed in the same way as time. Instead of working as criteria for the design, time and costs have been the driving factor for the process.

A construction project's success is often affected by its ability to meet three constraints: time, cost, and quality (Atkinson, 1999). This is illustrated as figure 5 and is often called the Iron Triangle. If one of the constraints is changed it will affect the others, e.g. if the budget overruns and the project manager tries to reduce the costs, the other constraints will be affected as well. Most construction projects are failing at meeting the target for the project in at least one of these three constraints. Large construction projects have historically been having problems with time and cost overruns (Shane et al., 2009). By managing these three factors in an early stage of the project the risk of failing will be reduced (Kranker et al., 2016).

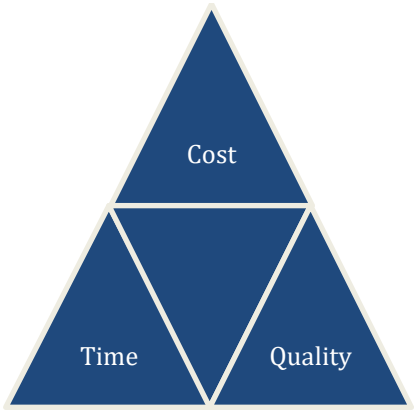

Figure 5: The Iron Triangle.

3.4.1 Controlling Costs in Construction Projects

Controlling the costs of a project is an important process, which can be done with cost control (Ballard, 2006). The definition of cost control is a balance between the cost of the building and its value which can be illustrated as the Iron Triangle, see figure 5 (Björk & Karlsson, 2012). Cost control is not only about what is going to be done, it is also about how it will be done. The cost control should be introduced early in the building process but should be checked up frequently. At the beginning of a project, the target should be on amount and quantity since this will reduce the risk to change the design later on in the

building process (Björk & Karlsson, 2012). Cost estimation is described as the process of predicting and evaluating the total cost of a job during a given time by using available information and resources (Ji et al., 2019). The need of an accurate cost estimation in a project increases over time, as well as the security of the final costs. According to Muñoz-La Rivera et al. (2019), one big problem with construction projects is that the budget is estimated early in the construction process, when little information about the building is avaible. The longer into the process, the more expensive a change will be (Muñoz-La Rivera et al., 2019). In the beginning of the process, i.e. in the design phase, the ability to influence project costs and changes is the highest. The longer time into the process the less the stakeholder has the ability to affect the project.

To control the costs in a construction project, target coting can be used. Target costing is a method that systematically tries to make the profit a criteria for the project through structured cost reductions (Ballard, 2006). The method comes from the manufacturing industry but has now been adopted and used in the AEC industry. First a target cost has to be set. This can be a complex and difficult process in construction projects compared to manufacturing projects. This is because initially in construction projects the architect produces a design and works together with the client to understand their requirements (Ballard, 2006). Then a facility design is produced to deliver these requirements. The facility design that the architect produces is often found to be more expensive than the client is willing to accept, which leads to designs that need to be revised. This cycle to redo a design wastes both time and capital. By using target costing the design will become cost driven. The cost driven design will potentially lead to a reduction of waste and an increased value of the project. Target costing encourages managers to influence the overall cost and the impact it gives on the project's life cycle. This gives the design team the ability to make design changes which will reduce costs (Hansen et al., 2007).

3.4.2 Purchasing Process

Purchasing is an important part of a company's value chain. Weele (2018) describes purchasing generally as *"The management of the company's external resources in such a way that the supply of all goods, services, capabilities and knowledge which are necessary for running, maintaining the company's primary and support activities is secured at the most favorable conditions covering the materials, information and money flows up to the point of consumption".* According to Bildsten and Manley (2015), the purchasing process in construction involves eight steps. The first step is to *identify the need* of the clients. The second step is to e*stablish the specifications and scheduling the purchase.* Depending on if it is a material or a service that will be executed, different identifications are needed (Weele, 2018). For material supplies, either a functional or a technical specification are established and for a service supplies the method to produce the service will instead be established. The third and fourth step is *identifying purchasing alternatives* and *evaluating alternative purchasing actions,* which is to identify what is best for the project and who will deliver the results that are expected of the project. The fifth step is to *select the suppliers* that fit best to the task. Step number six is *negotiating and contracting,* this is to get the best possible contract with suppliers. The last two steps are *issuing the contract or order* and *following up,* this is done to secure that the purchases live up to the predicted expectations and that the order are delivered in the right time and with the right quality that are paid for.

One of the most important steps in the design phase according to Benton and McHenry (2009) is the material selection process. The selection of suppliers should be based on the suppliers value-based capabilities and not only on a competitive procedure. Weele (2018), points out the importance with a structured decision making in the purchasing process, otherwise it can lead to frustration due to loss of time and overrun in budget. Time is one factor that is critical in the construction industry, the project owner sets fixed start and end dates and if the project overruns it will be costly for the contractor (Benton & McHenry, 2009). Managers usually only pay attention to suppliers that provide them services and material that they can get for a low price, a high quality, and a short lead time (Wang et al., 2017). Lead time is the time it takes for a piece of material to cross the flow, from the start of the process until its ends (Koskela, 2000). One thing managers miss to consider according to Wang et al. (2017) when choosing the supplier is the suppliers' flexibility performance, environmental performance, and risk management abilities. Wang et al. (2017) also states that in the construction industry a significant amount of resource waste and delays in information are due to an unsuitable management of the supply chain of materials.

According to NCC (2019b), purchasing stands for 75% of the total building costs and the purchasing process therefore has a big impact on the total cost of the building. The purchasing process is not only affected by time, cost and quality, but also by relations (Ottosson, 2009). With good relations to the subcontractors the contracts are easier to negotiate so both parties of the contracts become satisfied. Ottosson (2009) mentions that it is important to enter a negotiation with a clear negotiation strategy to maximize the chances to be able to get a good price. There are two different strategies when signing suppliers, either by long-term agreements or directly purchasing from the spot market (Li et al., 2009). A long-term contract extends at least over two years while a short-term contract extends over a shorter period. Li et al. (2009) concludes that using a long-term contract results in minimized risk because of long-term agreements have a smaller change in the expected total cost. To create long-term partnerships with suppliers creates benefits for both parties (NCC, 2019b). These benefits arise because similar goods can be utilized in many construction projects that both parties collaborate in.

According to Aretoulis et al. (2010), one of the most important activities the purchasing team has is selecting the suppliers. Hence selecting "correct" suppliers can lower purchase cost and improve the competitiveness for the company. The finding of appropriated suppliers that can provide the building with right products or services with the right quality, price and in the right time to the building site is an important factor to consider when monitoring and controlling the costs of a project (Aretoulis et al., 2010). According to Cengiz et al. (2017) recent studies have shown that the quality has become the most important factor to consider when choosing suppliers, closely followed by delivery and cost.

3.5 Digitalization

In general, digitalization can be defined as a transformation of information that earlier where presented analogous becomes digital (NE, n.d.). In a more business-related approach, digitalization can be explained as a way to change existing business models by using new digital technology (Gray & Rumpe, 2015). According to Byggindustrin (2018), the Swedish construction industry is one of the least digital industries. Although most of the companies think that digitalization is important to increase the productivity and efficiency in their processes, only 39% have a strategy of how to become more digital. Except improved productivity, Aghimien et al. (2018) present further benefits to gain from digitalization in the construction industry, for instance savings in time, improved quality of documents, and more easy ways of working.

3.5.1 Virtual Design and Construction

To create a framework that increases the integration within a project, Virtual Design and Construction (VDC) is a practice that can be implemented in construction projects (Kunz & Fischer, 2012). The VDC practice can help the construction industry to work with lean principles such as reduce cost and waste, and increase the productivity (Alarcón et al., 2013). The VDC-term was introduced in 2001 at Stanford University at the Center for Integrated Facility Engineering and is defined by Kunz and Fischer (2012) as *"the use of integrated multi-disciplinary performance models of design-construction projects to support explicit and public business objective".* VDC aims to link design and construction project management with systems used in financial and product management, which before the time of VDC has been performed manually to high costs. The driving force behind the development of VDC is to integrate Product, Organization, and Process (POP), and attain a more efficient way of information exchange between different computer systems (Kunz & Fischer, 2012). The POP-model is a tool useful for project managers to control the product, organization and process. Meaning the buildability of the product, the structure of the project organization, and the process between design and construction in terms of milestones and activities to get there. In other words, the POP-model consists of building components to be built, the organization behind who is going to design and construct the components, and how it should be accomplished. The POP-model specifies and describes information of the individual product, organization, and process models, and is not one complete model itself.

Building Information Modelling (BIM) is a similar way of working compared to VDC. However, BIM only includes the product aspect of the POP-model, i.e. the building elements, and does not include organization and process (Kunz & Fischer, 2012). BIM can thereby be seen as a subset of the content of VDC. BIM mostly refers to adding information to an information model, but the practice of VDC is about more than just the technology, it also includes the involved people and their knowledge and skills (Andersson et al., 2016). Andersson et al. (2016) states that VDC is the implementation of processes and new technologies, and the integration of these technologies to the project. According to NCC's (n.d.-a) definition of VDC, BIM is presented as one part of the concept. NCC divides VDC into four parts: *collaboration*, *BIM*, *processes*, and *metrics,* which can be seen in figure 7. Collaboration refers to the work between the different parties in a project. BIM is a way of working to both create and manage the project's information. Using BIM enables the possibility of doing quantity takeoff from the BIM model, coordinate work efforts, perform clash detection between disciplines, and visualizing the time schedule. Processes are

about supporting the core field of the company. Finally, metrics refers to value measurement of actions that have been made. By implementing VDC, the employees get a greater understanding of the whole project. Additionally, VDC means that the right information can be obtained at the right time during the project.

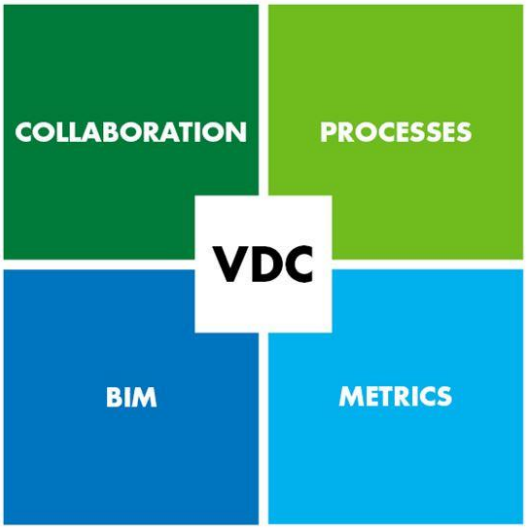

Figure 6. The definition of VDC according to NCC (n.d.-a).

Kunz and Fischer (2012) presents a three-level maturity model of the implementation of VDC in an organization. The first step is visualization, meaning that models are used in individual projects to increase the understanding and support decision-making. Models that are used in this stage are 3D-models of the actual product, but also models of the organization and the process. The second step in the maturity model is the integration phase. In this phase, previous models from the visualization phase are integrated with each other which require data sharing and collaboration between multiple stakeholders. The third and last step is automation. Designing in projects at this phase means that automated methods are used for efficient and effective routine design, which require well working integration and visualization in the previous two steps.

In the field of VDC different techniques and tools have been developed from the POP concept (Khanzode et al., 2006). Tools for visualizing the product element, for instance 3D modelling in Revit or AutoCAD, are applied in VDC to increase the comprehension of the product before the construction is finalized and to coordinate work among different disciplines. 4D visualization can further be attained by combining product and process modelling, meaning that the time aspect is brought into the model that in addition to 3D visualization also shows the construction of the building over time. The fifth dimension, 5D modelling, means adding the cost parameter to the information model (Lee et al., 2016). The intention of 5D is to deal with the problem of doing cost estimation early in a project when lack of information makes the estimation difficult. By implementing 5D to the framework of VDC and its multi-disciplinary models, intuitive checking of the building elements' properties can be done, and then in a more accurate and consistent manner. Shared models of the product also reduce the time for estimations by extracting required quantities from the model (Khanzode et al., 2006). By using the different virtual tools of the POP-model, various of interference in the project can be addressed, analysed and understood in an early stage of the project due to the simulations that can be made of the project delivery of a construction project (Khanzode et al., 2006). Further on, the tools

simplify the coordination between disciplines and creates effective communication due to the more realistic presentation of spaces.

From the implementation of VDC, not only have not new models of communication emerged, new roles in the AEC industry have been created as well (Gustafsson et al., 2015). The research by Gustafsson et al. (2015) shows that VDC can have positive impacts on the quality and result of the project, that VDC creates work processes with higher efficiency than the traditional approach, and increases the profitability in general of the company. Although, the research shows that the success of a VDC project is dependent on the VDC professionals' presence. The VDC professionals are mostly involved during the design and construction phases of a project, but are according to Gustafsson et al. (2015) needed to a greater extent in other phases such as tendering and delivery to the client where the involvement currently is low. However, an increased overall involvement of VDC professionals during all project phases are desirable.

3.5.2 Quantity Takeoff

Quantity takeoff is one part that needs to be made before purchasing of material can be done. The quantities in the building are measured and used to estimate costs for both material and the workload that is needed to execute the job (Monteiro & Poças Martins, 2013). Traditionally in the AEC industry, cost estimations were made by hand out of 2D drawings but nowadays BIM is used more. Using BIM makes it easier to get the underlaying information that is needed for the costing. If changes in the model are made it is easier to change the costing, compared to when it is done in 2D drawings (Cho & Chun, 2015). The information needed for costings is often area, volume, quantity, components, and building parts. When the calculation is made in an early phase of the construction process it is often based on the information such as area and volume. When using BIM, the object in the model needs to have the underlaying information, this underlaying information can be added from e.g. an architect.

In 1979, Svensk byggtjänst came out with a system called BSAB (Svensk byggtjänst, n.d.). This system consists of codes for different types of components, component types and resources. Each part in the model will be named with this code to easier classify the parts. The BSAB system tries to make the AEC industry speak the same language. If the industry is speaking the same language the communication will be better and mistakes can be prevented and by that save money. A newer version of the BSAB system is called CoClass, this was invented to adapt to the industry's continual growth of digitalization (Eckerberg, 2017). By using standards when classifying a model, Eckerberg (2017) noted that it reduces the preparation and administration work and leads to better information extend during the design phase.

3.5.3 Level of Development

The LOD describes the level of BIM used and can be referred to either Level of Detail or Level of Development (Kensek & Noble, 2014). LOD sets the level of how detailed an element should be in the BIM model. Thus, how much data all components in the model should contain. To distinguish the terms Level of Detail and Level of Development, the Level of Detail means how much details that are added to an element (Latiffi et al., 2015). On the other hand, the Level of Development refers to how reliable the information in the BIM model is as an output to the project members. The term Level of Development is

further used as the description of LOD. The LOD is divided into different levels which each level presents the minimum amount of data to add in the model (Kensek & Noble, 2014). The data can for instance be quantities, dimensions and spatial data, but also data such a product data or the manufacturer. The LOD is divided into levels between LOD 100 and LOD 500 with an increasing detail level (Beetz et al., 2018). LOD 100 is the lowest level meaning that the element is only presented graphically in the model as a symbol. The next level is LOD 200 where the element is a generic element containing of approximate data of dimensions and locations. In LOD 300 the element is represented as a specific object with accurate dimensions, size and location. In LOD 350, the element is represented as LOD 300 but is linked to other elements in the model as well. At LOD 400 product specific data of the manufacturing of the product is further added to the element. Finally, at LOD 500 the geometry of the element has been verified on-site.

4 Empirical Findings

The empirical findings focus on NCC and two of its large building projects located in Gothenburg. In this chapter a brief description of NCC is firstly presented follow by two case studies of the investigated projects.

4.1 Overall Description of NCC

NCC is a building and real estate development company operative in Nordic countries (NCC, n.d.-d). NCC is one of Sweden's biggest construction companies developing both commercial and public buildings, but also roads and infrastructure. NCC is divided into five business areas: NCC Infrastructure, NCC Building Sweden, NCC Building Nordics, NCC Industry and NCC Property Development (NCC, 2019a). This master thesis focuses on NCC Building Sweden.

The following sections consists of collected material from two interviews and internal documents from NCC. The interviewees have no direct connection with the projects in the case studies but work as central resources at NCC. One of them is a leading technical specialist (TS), that connects the network of installation leaders within the company and manages information from central purchases where agreements are made with suppliers. The other one is the head of design and installation control (HD), working with internal processes in these areas. To facilitate the reading the acronyms TS and HD are used.

4.1.1 Internal Processes

NCC has an internal business system, which describes every step of the processes during the pre-design, design and construction phase of a project. The connection between purchasing and the design team is however not that clear in the design phase. The connection and involvement of purchasing is however more clearly described during the construction phase. The HD describes how the design phase looks at NCC today and says that *"If we are looking from a design managers point of view and how a design manager is managing and leading a group of consultants, it looks good. We have clear processes how to plan and execute the design. If you look upwards in the organization of how to plan and manage the internal work, there are no processes about this"*. The HD mentions that when there are no clear processes on how to run and manage internal work, HD points out that the collaboration between purchasing and the design team will differ from project to project depending on the purchaser's previous experiences. The HD further explains that, if there is a purchaser with a lot of experience, the communication will be facilitated between the design team and purchasing because the purchaser knows what is needed for the purchase. On the other hand, an inexperienced purchaser needs more support in this process which can be facilitated with an experienced design manager (HD). The knowledge about what is needed for purchases will then come from the design manager instead of from the purchaser.

There exist several different types of entreprenerd contracts and depending on which type of contract the connection and collaboration can vary between purchasing and the design team. Both projects observed for this thesis has been based on partnering agreements (in Swedish "samverkan"), and TS points out that at NCC it is nowadays a common agreement to work with. The HD mentions that in recent years there has been a shift from a traditional type of contract but today it is more common to work with partnering. Before, NCC received a finished schematic design that was being priced and

after that the construction documents were produced (HD). In the conventional way, there are clear and already defined directions from the client about what is being produced. When working in partnering projects, the HD mentions that there is a larger focus on collaboration and early involvement in order to both address challenges early as well as having the right knowledge available to solve challenges in the best interest of the project. Furthermore, when entering a partnering agreement, there is not always a finished proposal drawing which leads to higher demands on getting a common understanding of the project (HD). According to the HD, the involvement of purchasing during the design phase varies between NCC's projects. In projects with a high degree of collaboration, like partnering projects, purchasing is often involved earlier in the process compared to other projects (HD). The TS highlights the difference between working with partnering and not working with partnering projects, where it affects when purchasing should be involved. According to the TS, purchasing should overall be involved as early as possible in projects, and for a partnering project it is even more important with an early involvement.

4.1.2 NCC Projektstudio

NCC Projektstudio is a working method based on lean construction that is applied during the design phase at NCC (NCC, 2020). NCC Projektstudio will further on in the thesis be referred to as Projektstudio. The working method aims to increase the understanding and trust, and to improve communication paths for all actors in the design phase, both internal and external. The working method is based on collocation, collaboration, and Virtual Design and Construction (VDC). Collocation means facilitating an increased face to face communication, where the project should have specific collocation days where all actors are working at the same working place. These collocated days enable both formal, but also informal meetings among the project team. Collocation also increases the trust building between project members which is essential for almost any type of collaboration, where it is independent whether the design members are internal or external. Collaboration, which Projektstudio is based on, means exchange of knowledge. This way of learning and getting an increased understanding for the projects combined challenges among all team members is the essence of the work method Projektstudio. VDC entails the use of standardized information and that all involved project members have access to information from the same source. The design manager should therefore have support from a VDC-manager and VDC-coordinator in Projektstudio. The VDC-manager is responsible for the information flow and the VDC-coordinator is responsible for coordinating the BIM model. In some cases, these tasks can be handled by the same person. A way of working with Projektstudio is to use visual planning. To facilitate the visual planning in Projektstudion a planning method called pull-planning is used, which is a joint time schedule. To identify how to reach the end goal, the right information must be pulled. A pull-system provides an understanding of the project as a whole and how important every part is in order to reach the final goal.

The vision of Projektstudio is to create a structured way of working for all of NCC's projects, thereby securing a higher minimum level of understanding (NCC, 2020). By encouraging a shared responsibility among all involved design members, errors will be discovered early and be prevented, which helps find higher quality solutions. Working with Projektstudio as a standardized working method, expected results on the project will hopefully arise. One of the expected results is an even and controlled flow of information,

resources and economics. Another expected result is to lower the total cost of the project due to the elimination of waste.

4.1.3 Purchasing

When wrong deliveries are made in a project, it is often due to the fact that the assignment is incorrectly defined (TS). Thus, the definition about what should be designed, and which investigation should be made. It happens in projects that the consultants designing details which is not needed. Therefore, it is important to make clear limitations in the purchases and to prioritize documents. In the prioritizing list, the contract comes first, and the tender is prioritized last. The TS mentions that if the tender is prioritized high, a lot of documents lose its value. The tender should therefore not be highly prioritized and reservations that are important should be written in the contract. To reduce risks of wrong purchases, purchasing should be involved as early as possible in the project, according to the TS. To reduce the number of mistakes in the project that leads to inaccurate purchases, NCC also uses a PIP time schedule. PIP stands for design, purchasing and production where the time schedule between these three phases integrates.

As a purchaser the knowledge level overall needs to be high (TS). Everything that stands in the proposal drawings, project planning documents, and building documents must be recognizable. A purchaser needs to be familiar with the contract long before a purchase can be made. The TS sees a lack in the knowledge level of the purchasers, especially when it comes to detailed knowledge. One reason for this is the time constraint a purchaser has, which does not provide time for closer reading of the topic in advance. The time constraints are so narrow that the TS thinks the purchasers prioritize wrong and that purchasers do not see the importance of being briefed.

4.2 Masthuggskajen

The empirical findings of Masthuggskajen are mainly collected from interviews with five project members. The interviewees are Design Manger (DM), Project Manager (PM), Project Purchaser (PP), VDC-coordinator (VDC) and fire consultant (FC). To facilitate the reading theses acronyms are used for all interviewees.

4.2.1 Overall Description of Masthuggskajen

Masthuggskajen is an area located close to the river in central Gothenburg where a new neighbourhood will emerge on the initiative of Gothenburg City (Älvstaden, n.d.-a). In the neighbourhood approximately 1300 new dwellings are going to be built, and 5000 to 6000 workplaces are being developed. The ambitions of creating a sustainable area is high and Masthuggskajen is the first project which received a Citylab certificate for sustainable neighbourhoods already in the planning phase of the project. The development of Masthuggskajen is being built by a consortium of six construction and real estate companies, where NCC is one of them. NCC has two projects in the area, a workplace building called Magasinet and another project consisting of two buildings called Våghuset and Brick Studios which also will be offices (Älvstaden, n.d.-b). In this case study, the project that consist of Våghuset and Brick Studios has been investigated. Both Våghuset and Brick Studios is certified by the environmental certification BREEAM (NCC, n.d.-b). Våghuset will be a building of 13 levels and 10 000 m^2 of workings space (Våghuset, n.d.). Bricks Studio on the other hand will consist of 15 levels and 15 000 m2 working space (Brick Studios, n.d.). Both buildings are expected to be completed in 2022.

The project is a partnering project that has a Design-Build (DB) type of project delivery (DM, PM). NCC Property Development is the client and NCC Building is the contractor for the project. The schematic design was finalized during the autumn 2018 and the project is, at the time of executing the case study, in the detailed design. The detailed design is planned to be finalized during autumn 2020 (PM). The construction phase initiated in September 2019 and is since then done in parallel with the detailed design (Brick Studios, 2019). When the case study was executed, during spring 2020, the construction was in the phase of doing ground and piling work (PM). The construction had a delayed project start due to problems regarding permits and authorities, and was by the time of the interviews two weeks behind schedule.

4.2.2 Collaboration

The design team at Masthuggskajen works collocated during the phase of pre-design. Two days a week the client, project purchaser, designers, etc. works collocated at the project office on-site. During these two days the project members are working according to NCC's working method Projektstudio. These two days are used as a way for the project team to collaborate and visualize things together. This is often done in small meetings kept to those who directly are involved in the topic. Every second week the project has a big design meeting where the overall schedule and larger questions concerning everyone in the project are brought up. No decisions are made at these meetings, and they are used for information sharing about decisions that have been made. This information meeting is scheduled for three hours and a system called Apricon is used. It is a system where all upcoming questions among the design team members are initially asked. In this system all questions are saved and can be traced in a so-called pull-system. In this big design meeting, all disciplines are represented except purchasing. This is something that the project purchaser has decided together with the project management. The decision to exclude the project purchaser in this meeting has been made to save both time and money. The design manager points out, when talking about Projektstudio and effective arrangement of resources that *"I invite between 40-50 people, to attend these meetings and it is difficult to run meetings with 40 or 50 people. In those big meetings it is just information spreading, there is not much of a discussion. So, you can say they are very expensive or ineffective meetings. So, what I do is that I divide the design into many different groups. There will be many smaller meetings that are then gathered in a group where the decisions are made".*

During the two collocated days all design team members must be at the collocated worksite, but it is not obligatory to stay at the workspace to work when there are no meetings. However, it is recommended that employees stay to be able to answer any upcoming questions from other design team members. It is more common that people work at the project office during detail design, than schematic design, due to the fact that there is more coordination needed and more details to be discussed and solved in this phase. Overall the collaboration between purchasing and the design team has worked well (DM, PM, FC, PP). This is because the purchasing is sitting close to the design team, which facilitates a close dialogue. This makes the purchasing work easier, since it is necessary for purchasing to have contact with different designers depending on what the purchase is. The project purchaser also has a close dialogue with the design manager before a purchase is made, and concerns and questions are discussed between these two (PP).

The workload for the purchaser varies in the different phases of the project. The schematic design, which is the first involvement in the project, is a relatively calm phase for purchasing. It is calm until the tender calculation starts, where the workload is at its highest. For the tender calculation, the purchaser needs to ask suppliers for prices. The PP talks generally about the workload as "*it has worked well but it has been quite hectic since I have been by myself… so there has been a lot to do".* The purchaser is involved in the Projektstudio days and attendees to some of the small working meetings. The project purchaser with the help of the project management, selects a few small working meetings to be involved with and is often involved in the first four or five meetings. This is to make it clear what to purchase, who is going to make the delivery, and to create delimitations for each purchase. When the design starts to become more detailed the less time the project purchaser needs to be involved in those small meetings. During the detailed design phase, the purchaser is involved in purchasing meetings that are held once a month. These meetings are together with the client, project manager and production manager. The agenda of the meetings is the purchasing plan, where the objective is information sharing and the discussion is about the progress of the purchases.

According to the PP, the production is the most important part of the project and purchasing's work is a support function to serve the production. Before a purchase is made, the purchaser involves production and asks how production wants material to be delivered on-site. All information about delimitations and what is included in the purchase has to be passed on to the responsible supervisor when the production starts. Most of the communication between the purchaser and the responsible supervisor are during the detailed design phase. This is because nothing is produced during the schematic design phase.

The fire consultant, which is contracted as an external resource participates in the Projektstudio days. The fire consultant's contribution in the development of the design document is limited. However, the fire consultant tries to be included in a lot of meetings. The fire consultant considers the collocated workdays important, *"I am not involved in everything, but I´m involved in most of them, because it is important for me to keep the overview of the project*" (FC). The time that the fire consultant is spending in the project has decreased during the detailed design phase, as the majority of the fire related challenges were handled during the predesign, *"Masthuggskajen is purely an office building, this means that questions were solved earlier and now in the detail design, I can be more on distance in the project" (FC).*

The design manager collaborates with purchasing, designers, production and planning in parallel with the design development (DM). The dialogue between the design manager and project purchaser is good and typically daily. The project purchaser is not aware of any flaws that can be connected to lack of communication between the project purchaser and the design manager. This is because the design manager is very strict about documenting, *"If it is not documented, it is not an agreement nor information*" (DM). Once a decision is made, it becomes documented. The fire consultant has noted that the project has a fast decision path and thinks that the collaboration has been good because of feedback that arises early in the project. Because it is a DB project, where the production begins when the design is still being processed, feedback comes naturally. By having a DB contract, the project purchaser is involved in an earlier phase of the project, compared to

DBB, where the material is purchased, and suppliers are contracted after the detailed design is finished (FC).

In the detailed design phase, daily communication between purchasing and design team occurs (DM, PM, FC, PP). During this phase the project purchaser has the ability to ask for complementary data or information, if there is something that needs to be clarified. During this communication the design manager is often involved to ensure that the information exchanged is correct (DM). Therefore, most of the information goes through the design manager. In the schematic design the project purchaser and the design team communicate more rarely (VDC).

An improvement in the structure of the project has been needed in earlier phases of the design, since the process and planning had deficiencies (DM). This could have been solved with better planning and more staff. During the design phase all information that should be handled, is during a very short period of time and according to the DM *"This resource [more staff] can be hard to handle, and to involve a resource that is just involved for a short period of time and therefore does not understand the house or the complexity of the product. It is quite difficult to get involved in such a project in a short period of time... After all, you need to find a resource that can have multiple purposes in the project. Preferably a resource that can help the purchaser and help planning this while that resource can go ahead and do other things when that need has disappeared… these are the resources that are difficult to manage".*

A challenge between purchasing and the design team is that it is not clear how much information is needed in order to carry through a purchase. The PP explains this when talking about challenges in the design phase, *"I want to have as much information as possible to be able to make a good purchase... while the designers might want to purchase something as early as possible to be able to have someone to talk with"*. Better balance between when something must be purchased and directions on what type of information that is needed has to be established, as much of the design documentation is not ready before the end of the detailed design (DM). The optimizing is necessary to find the right product with the right quality. The more detailed the design is, the more suppliers can be contacted leading to a better optimized price. Because only a few people are working with purchases, design, and managing, it is hard to produce all the relevant data in time. Since the purchases are happening concurrently with the design and production development, it cannot be as optimized at the detail level (DM).

4.2.3 Costs

All the interviewees were aware about the cost of materials and labor in the project and how it affects the project. The design team works with cost awareness in different ways, for instance by trying to find the most cost-effective and highest quality material when choosing components (PM). The project is also working with cost awareness in a value perspective, so that no work is done that does not create any value for the project. This way, money is saved, and risks are reduced (VDC, PP). The PP explains that *"on paper a purchase can initially look good, but in the long run if it is poor quality it can become more expensive. Every purchase needs to be complete which means that every choice needs to be well thought-out until the building is handed over which includes all costs. Therefore, I as a purchaser need to have everything in mind and that all costs are considered all the time".* To be able to make complete purchases, a dialogue with the supplier is needed about how

the deliveries will be made. The project has a responsibility to optimize the costs on the materials in the project, but also the cost of consultants (DM). The same responsibility is necessary to make the project with right quality, and if it is possible, to make it faster and more cost-effective. A balance between the three factors in the iron triangle, cost, time and quality, are included in the target of the contract (DM). In the project, the design team has a clear cost control goal. The design manager is involved in this work and is responsible for the design of the product. The design manager must ensure that the design matches the target cost.

Target cost control is something the design team has used (PM). The people that are involved in the work with target cost control are the project manager and the assistant project manager (PM). All interviews are working with target cost control to a larger or smaller degree (PM, PP, FC, DM, VDC). For example, the fire consultant works with cost control with their own project budget and controls their consulting money. Another example is purchasing who breaks down the budget into different items to reach the target cost. After every purchase or contract, the purchase target is controlled. By breaking down the target cost into smaller parts, it makes the target cost controllable (PP). When talking about target cost control, the project manager says "*to be honest, I have been kind of bad at this. Because we have had a target cost for the whole project, and it is on X amount of money and then you divide this with [the client] … you share the income and costs against the target price. You have a goal, which I have honestly been pretty bad at... you can set sub-goals, that is how much we want to earn for that activity. Or a sub-goal, that you want to be faster in the contract. In this project we are now under a lot of pressure in the contracting with both time and money, so this is already a goal that you should be keeping to. But it is often a good incentive to have sub-goals… which I have got complaints about from my co-workers, that we have not had any".*

The project team had to make a saving round in the project after a requirement from the client. The building was too expensive as it was designed, and therefore it was necessary to make it cheaper (DM). This was because of a requirement of the revenue claim that the design had not achieved. In the project an important discussion about cost has been about the air ventilation system (FC). In the beginning of the project, an estimation about the cost for this system was taken from a reference project. After this reference project was built, the regulation for the system has changed which was not considered in the calculation. The system that was used for the first calculation was therefore not useful. This resulted in a much more expensive system than anticipated and the client needed to rethink the cost constraints about this system (DM).

4.2.4 **Use of BIM**

In the project, both 2D drawings and 3D models are used. The 3D model is used for two purposes in the purchases (PP). The first one is for the subcontractor and suppliers to visualize the project and create an interest. The other purpose is for quantity takeoff (PM, DM, PP). By taking out quantities of a model, instead of counting with a scale bar and calculator, the amount becomes more accurate (PP). The 3D model is not used in purchases because there are extremely few subcontractors that are able to understand the model. Therefore, a purchase is often based on official building documents, 2D documents. Although, when an inquiry for a contract is sent out, the model is almost always attached if the subcontractor wants to use it anyway. The main reason the subcontractor uses the model is for quantity takeoff and visualization but also to make

specifications in excel. The model can sometimes be used to double check the subcontractor or supplier's bid, so that the right amount of material is brought to the site (VDC). In this project for the purchases of both the frames and facades, the model has been used more than in other purchases. This is since these two components are more mature when it comes to handling a model (PP).

At the end of 2019, the VDC requirements were incorporated in the design instructions (VDC). Before the design phase, the VDC department define all parameters that are needed in the BIM model. These are the parameters that both production and the purchasing need, which is used in the design instructions (VDC). The project purchaser has been involved in the work of defining those parameters but not on a project level, more in an overall perspective for NCC. The design instructions that the VDC department bring forth consist of VDC requirements, that goes down on which level of detail (LOD) an object in the model should consist of. By defining those parameters, it prevents designers from putting too much information in the model. Without the requirements, extra work would have been done since unnecessary information would be added (PM). When the LOD requirements of the model are set, the VDC department asks purchasing for input and the design manager has noted that *"purchasing does not have that much input in this work except to convey information about the supplier's ability" (*DM). The fire consultant says that *"They [purchasing] have comments on which parameters that should be visually described in order to make as good of a purchase as possible. So, to a certain extent they are included in the background".* These LOD requirements are set without the fire consultant's input (FC).

BIM models have a lot of information and the design manager tries to optimize the model after the employee's knowledge (DM). If someone in the project team does not know how to use the model, the model will be used less effectively. Since a lot of consulting hours are spent adding information into the model, this would result in a big waste of money and time if the model is not fully used. Whether it is the model or 2D drawings that are being used depends on what is the most cost-effective for that specific purchase (DM). This is something the design manager thinks needs to be considered at all time during the project to optimize the model. The DM explains that *"it is very easy when everyone says 3D, that you think that it is obvious that we should do it in 3D. But it is not always that obvious, because you do not always get a better product due to that. Often the product will be more expensive, because it is a lot of extra work. It depends on which phase of the design you are in and how many changes you need to do etc."*. It is also hard to make changes afterwards in 3D models because often a component is copied into a lot of different places. When one change is made in one place all other places need to be changed as well. The AEC industry is working towards more digitalization (FC). The fire consultant that barely works with the model thinks that the fire discipline also needs to follow this but has for the moment not found a tool for fire documentation that facilitates the work.

The fire consultant explains that it does not matter to them whether purchasing is involved more in the development of the BIM model. The only reason the fire consultant believes purchasing would have an interest in being more involved in the development of the model is to be able to follow-up on earlier purchases. Purchasing would be able to know what opportunities there are for improvement and be able to find more cost-effective solutions. The fire consultant also mentions that collocation of various disciplines during pre-design and detailed design enables the development of more cost-

effective solutions earlier in the design phase. The project purchaser needs to be involved and put requirements on the model because otherwise the VDC-coordinator guesses what information the purchaser needs to have in the model (VDC).

In Masthuggskajen they have worked with a pilot project, where windows were going to be purchased using only the BIM model. All information was therefore put into the model and were then only sent to the one window supplier that could make purchases out of a model (DM). The model was used as the underlying document for that purchase. This model-based purchase would probably have turned out well if the window type was not changed. A change occurred because two different consultants were delivering different information into the model, causing a miscommunication. The only supplier that was able to purchase with the model could not supply these windows. As a result, suppliers that could deliver this type of windows that meet the requirements of the model were not able to read the model but were however selected (DM). The mistake slowed down the process of the project because the only information available was the model and this had to be redone. The VDC-coordinator says that *"I do not know if the problem occurred due to the fact that the information was handled data based or if this problem would happen anyway*". This is a new way of reviewing deliveries, and it is therefore important to educate everyone in the use of it to prevent mistakes like this in the future (VDC). This would prevent mistakes and misinterpretations to arise and by that ensuring that information that is delivered to the suppliers are transferred correctly.

4.3 Lisebergs Jubileumsprojekt

The empirical findings of Lisebergs Jubileumsprojekt are mainly collected from interviews with five project members. The interviewees are the Design Manger (DM), Project Purchaser 1 (PP1), Project Purchaser 2 (PP2), the VDC-manager (VDC) and a fire consultant (FC). To facilitate the reading theses acronyms are used for all interviewees. Lisebergs Jubileumsprojekt will further on only be called Liseberg.

4.3.1 Overall Description of Lisebergs Jubileumsprojekt

Liseberg is a project consisting of two buildings, one experience hotel and one water park (Liseberg, n.d.). This case study is focused on the first stage of the project, thus the experience hotel. The project follows the theme of Gothenburg's history and Ostindiska kompaniet. The experience hotel, named Liseberg Grand Curiosa Hotel, is a family hotel that aims to preserve the imaginative feeling of the theme park during the whole stay. The area of the hotel is 29 900 m^2 and will accommodate 457 hotel rooms with at least five beds in each room. Additionally, the hotel will have a restaurant and a rooftop restaurant, and some smaller conference facilities.

The project is a partnering project between the client Liseberg and NCC Building as the contractor (NCC, n.d.-c). The contract price for the hotel is approximate 850 MSEK. The project has a Design-Build project delivery (DM). The collaboration began in 2018 and since then have planning, budgeting and designing been going on (NCC, n.d.-c). Liseberg Grand Curiosa Hotel is by the time of execution the case study in the end of the detailed design (DM). The detail design phase started in October 2019 and is planned to be ready for review in the beginning of May 2020. The hotel was approved for construction start September 2019 and by the time of the case study, ground and piling work was executed (Liseberg, n.d.). The project as a whole is divided into two stages and for the second stage,

the water park, the schematic design started in March 2020 (DM). Both the hotel and the water park are planned to be finalized before 2023 when Liseberg has its 100th anniversary (Liseberg, n.d.). The project has high environmental requirements and has the environmental classification BREEAM at the level excellent (DM).

4.3.2 Collaboration

The organization of the project implies that the project members mostly are collocated at the construction site. This means that project members such as purchasing, quantity surveyor, installation management, and the project manager are collocated, as well as skilled workers in sheds close by the others. This organization provides a close and continuous dialogue between the design team and purchasing, which more or less occurs on a daily basis (DM, PP1). Purchasing most often has a dialogue with constructors, architects and the design manager in the design team, and with disciplines such as fire it occurs more rarely (DM, PP2, FC). The fire consultant does not have direct communication with purchasing, since the fire discipline prescribes a solution which ventilation then designs and is then purchased by the purchasing department (FC). If changes are needed according to purchasing, the communication process is revisited by each discipline again.

The project works according to the design concept Projektstudio which means that the project members meet two days at the project office on-site and work collocated. One day a week starts with a short meeting, around 30 minutes. All participants involved are invited to the meeting, such as all the different disciplines in the design team, client representatives, purchasing, design manager etc. During these days there are several working meetings that different involved disciplines participate in. During the design phase the digital tool Apricon is being used, which is also the basis for the large joint design meeting once a week. Apricon is a sort of delivery board, which also are available in physical form with post-it's at the project office. Through this application project members address issues, both targeted and untargeted, that is reviewed during the meetings. All the decisions that are made are documented in Apricon (DM). Purchasing is invited but usually do not attend to the big design meetings that take place once a week in conjunction with the collocation (DM, PP1, PP2). Instead purchasing takes part of what is being discussed during the meeting via Apricon and PP1 points out that *"I do not use it [Apricon] that much but I read what is being discussed. It is like a log I read. So that is how I get the information, so I do not need to participate".* Purchasing sometimes gets issues addressed to purchasing in Apricon, and thereby gets the information and tasks that way without needing to attend to the meetings (PP2). The ambition from the beginning was for PP2 to participate once a week to sit down and listen to what is said and understand why decisions are made, but there has not been enough time. Participating in these meetings may also result in more workload for purchasing since questions regarding the budget in different purchasing items and costs of design solutions are often being raised. These types of questions require that purchasing requests suppliers or subcontractors and cannot therefore be answered quickly. During the smaller working meetings, the days the project work collocated, purchasing attends to some of the meetings.

At the Liseberg project, purchasing got involved during the calculation phase where a schematic design calculation was made to produce a target cost calculation to be able to sign the contract with the client for the next phase which is detailed design and production (PP2). During that time of the project, the workload for purchasing was very high. Since Liseberg is a partnering project many installers and consultants participate

during the whole project, and a large part of the purchases are made early in the design phase in the schematic design (PP1). During the schematic design consultants, and partially materials, are mostly bought since consultants such as electrician brings their own material. Installers correspond to a third of the budget and a large part of the purchases are thereby made early in a partnering project in comparison to a fixed price contract where the purchases would have been made later in the project. Afterwards in the detailed design, the purchases are mainly material. It is not until the end of the detailed design the workload decreases slightly since there is not much more purchases to be made until the detailed design is approved (PP2). In the project, there are specific purchasing meetings between purchasing, design manager, site manager, supervisors, quantity surveyor and project manager (DM, PP2). The meetings take place every second or third week and the agenda is to share ongoing and upcoming purchases. Regarding who participates at the meeting, PP2 points out that *"We do not make purchases without production. In other words, I always want production to be involved in the purchases I make. I am here for production and I will make sure that what it purchased should be easy for those in production".*

Involving purchasing more in the design phase is something all interviewees look at positively. It is unique that purchasing is involved this early in a project and often the purchasers enter a project late which implies that the task has mainly been to bargain and do the purchases (DM, PP1). An early involvement could mean that purchasing increases their involvement in finding good and more cost-effective design solutions, enables information requirements, gives the possibility to connect a supplier early in the project, and increases the experience sharing (PP1, PP2). As mentioned earlier, the purchasers do not participate that much in Projektstudio. To increase the involvement at Projektstudio could mean that purchasing can control the design phase and deliveries more by saying which documents are needed by what time so the purchases can be done on time (VDC). The challenge with this is that the purchasers have very much to do and do not have the time to participate at the meetings, but in one way that means that the workload will increase since purchasing will miss important information. Although, since purchasing's workload varies during the project, and is the most intensive in the beginning of the design process, adding more purchasers to the team may not solve the problem (DM).

All interviewees agree that the overall collaboration is good between the design team and purchasing. Due to the collocation there is a tight dialogue which facilitates and spontaneous discussions and questions (DM, FC). There is also communication between purchasing and VDC regarding which information purchasing needs and this is communicated by purchasing being involved in the development of the level of detail (LOD) for the project. How purchasing knows what information is needed and what requirement to put is based on experience and PP1 says that *"It is experience and my profession, so I should know it. And if I do not know it, then I have to find it out somewhere".* If purchasing needs help to get hold of information, either the design manager or VDC-manager may support. The design manager then helps purchasing to get the documents or books a meeting with the responsible person, and the VDC-manager sometimes helps to extract information or show where information can be found (PP2, VDC). It does not appear that there is any lack of information in the project, although it can be hard for purchasing to get the information in some cases. The large number of involved people makes in unclear who is in charge of the information and has mandated to decide, according to PP1.

Some challenges in the collaboration between purchasing and the design team are brought up during the interviews. The first challenge is that purchasing does not put up delivery notes on the delivery board of their deliveries and when in the timeline the deliveries are needed (DM). From a purchasing point of view the challenge in the collaboration is to understand how the design phase will be since it differs from project to project (PP2). For instance, which consultants and subcontractors are going to be purchased and when these resources need to be in place. To capture this early in the project can be challenging and sometimes a purchase may be needed earlier than originally planned. Further on, a language challenge sometimes occurs between purchasing and VDC, meaning that the VDC-manager talks based on BIM models and the purchasers based on their thoughts of which information is needed (VDC). Some information can be obtained in different ways and it is not always the BIM model that is the smoothest way. The requirement of what information should be in the model can thereby be a little high.

4.3.3 Costs

In the project there is a work regarding cost control for instance with change orders (in Swedish "ÄTA-hantering") and checking the project cost against forecasts (DM). There is one person working with cost control and the preparation of the forecasts, which mostly becomes a history of events, purchases, and the current cost of the project. The client has also required that there should be monthly controls of the project cost to see how well the project stick to the budget. For all purchases, purchasing has a certain amount of money to use for each purchasing item which is the basis for the negotiations and that sum capture everything about risks and extra cost for NCC (DM, PP2). This exact amount of money for each item is however not communicated to the rest of the project group (DM). The project purchaser 2 also works with purchase goals, meaning that each purchase should be on a certain sum but have its own goal on a sum below the purchase.

The early involvement of purchasing in the project means that purchasing has been more involved in the work regarding cost control (PP1). The reason why purchasing is involved early in the project is because of the complexity due to the unique sizes of rooms and the high BREEAM-requirement. The complexity of the project changed the economy, since in early phases ratio values from other hotel projects had been used, which did not match the Liseberg project (DM).

One of the main goals in purchasing is to lower the cost and this is done by trying to find the right quality that matches the client's need by for instance looking for cost-effective material choices (PP1, PP2). The importance of choosing the right quality means that a too good quality will lead to higher costs but with too low quality comes the costs afterward when things break, according to PP1. Further on, there is always a discussion in terms of extra time and cost in finding new solutions, and raised questions is always price assessed before being approved (DM, PP1). New design proposals entail additional costs by only raising the question and make an inquiry of the price. Investigations on new designs are therefore questioned if the time is worth it or not (DM). To have high requirements of information to BIM models is also a question in terms of time and money (VDC). The requirements are set by the VDC-manager in cooperation with inputs from other disciplines and departments such as purchasing. It is common wanting to build up

a model as complete as possible, but it is important to have the cost awareness of what the required information will cost to be able to produce cost-effective models.

It is not possible for NCC to control all disciplines in the project (DM). Architects, constructors, and fire- and sound disciplines are purchased directly by NCC and are the ones possible to control. Other disciplines like installation is purchased through partnering and a target cost, and those parties have in turn bought own consultants to do the design and it is those consultants working with the design team. The consultants are thereby controlled by the contract to the installer who will do the work in the production phase and not directly with NCC. The reason for NCC to purchase an installer instead of a consult is because it is the installer who purchase the material and produce the work on-site (PP1). The installer can thereby provide their consultant with inputs on the system and which solution is more expensive which becomes a cost control in that way.

4.3.4 Use of BIM

3D models, in combination with 2D documentation, are used in the project. The schematic design was made as a BIM model which in IFC-format was sent to the frame supplier, quantity surveyor and purchasing, among others (DM). Purchasing uses the model by doing quantifying thru the model in Simple BIM (DM, PP1, VDC). This is mostly done by the purchasers themselves, but in some cases the VDC-manager provides information from the model to the purchasers. Models is also used for visualization in meetings with suppliers and is sent in the purchase inquiry (PP1, PP2). Although, it depends on what is being bought and how much is included in the model. It is currently not possible to only rely on the model (PP2). Information that can be seen in a 2D drawing is sometimes missing in the models. Technical descriptions do not appear in the model and also affects to what extent the model is used. Whether models or drawings are sent to suppliers or not depends on the suppliers and their ability to handle the models (DM).

The fire discipline does not work with BIM models and instead deliver 2D drawings. Although, the fire consultant uses the model in a review purpose and makes requirements in the door environments but that is mostly a text parameter that is inserted. There has been attempts to add the fire discipline in the model and it is a possible future scenario even though the fire consultant cannot see any major use of it so far. The challenge in adding the fire discipline to the model is that the discipline has not any physical objects but instead delimitations. For instance, the architect designs a wall which the fire consultant then adds requirements on. It is thereafter important that this wall does not changes, removes, or moves so that the requirements disappears, which can be a little bit unmanageable but not impossible, according to FC.

In the beginning of the project, the VDC-manager sets up a VDC-ambition together with the project manager and design manager to decide how to run the project with VDC and BIM. When the ambition is set the next step is to produce a design guide, the VDC-requirements, and the LOD-appendix, which is done by the VDC-manager and the design manager. The LOD is mainly done by VDC but has a dialogue with the quantity surveyor as well regarding what information is needed to make a sensible calculation. VDC also has contact with purchasing regarding the information and LOD in the design. This is done by reviewing different types of objects and discussing what purchasing need for type of information and in which phase the information is needed. The inputs from the purchasers can sometimes be a little too high and when asking purchasing about

requested information it is obvious that purchasing wants everything delivered (VDC). The high requirements will then cost more than it provides. When all requirements are set, these are communicated with all different disciplines in a big meeting held by the VDC-manager. During the meeting the VDC-ambition, requirements, and LOD-requirement of the objects are presented.

Purchasing is involved in the development of the BIM models to the extent that purchasing has a communication with VDC regarding what information that is needed in the model, but there is no involvement in the actual designing (DM, PP1, PP2, VDC). In the beginning of the project, purchasing was given the opportunity to say how the model should be designed and how it will be used by purchasing (PP2). For instance, how doors should be categorized and which dimensions purchasing want in the model to further facilitate for the suppliers. The requirement was then passed on to the design team by the VDC-manager (VDC). There has been no contact between the fire discipline and purchasing regarding what parameters purchasing needs but that does not mind the FC that much, *"For me, it does not matter that much, besides for self-interest that it is interesting to have a little more follow-up or be included in the follow-up. To know maybe how to improve or to find more cost-effective things in some areas".*

Information needed in the project's models are the information used for quantifying, how the delimitations looks like, and information that are sent in the inquiries (DM, PP1, PP2). This can for instance be measurements, quantities, but also categorization for the doors which is useful since it is easy to follow in the quotation which door is priced at what cost (PP2). One request of information from purchasing that has been discussed many times is to add metal details in the model since that part can be difficult to quantify from 2D drawings (PP1, PP2). To be able to search and extract that information from a model would facilitate a lot, according to PP2.

To use BIM even more can all interviewees consider, and it may affect the collaboration in a positive way. The understanding of other disciplines and their work, as well as the understanding of each other's needs between NCC and subcontractors will probably increase (PP2, VDC). The understanding enables new ideas and better solutions when the needs are clearer (VDC). Team members must also coordinate their work in an earlier stage and communicate with each other (FC). However, the challenge partly lies in the hand of the suppliers and subcontractors and their digitalization and knowledge of finding the information (DM, PP1). Models are used a lot and much information is added in the models, but the recipients are not that digital yet (DM). Another challenge with working more model based is the possibility to add all type of information to the model and technical descriptions which can contain of fifty pages of text, pictures, clarifications and requirements is one example that is difficult to present in a model (PP2). Regarding having all information in the model PP1 points out that *"The model is just a tool. If it does not facilitate, it should not be used. Then something else should be used. There is not any compulsion in using a model"*.

5 Analysis and Discussion

In this chapter the empirical finding will be compared and discussed in relation to the literature review. The chapter is organized in accordance to answer the three research questions.

5.1 The Involvement of Purchasing During the Design Phase

Firstly, there are no clear directions or processes regarding purchasing's involvement in the design phase at NCC. When looking at the core processes of NCC, purchasing is not mentioned at all during the design. This is also confirmed in the interview with the head of design and installation control at NCC where it appears that there overall is lack of internal processes regarding what inputs and outputs purchasing, and other internal departments, needs. Since there are no directions of how and who to control this exchange of information, there will be no certainty that the dialogue about inputs and outputs occurs. It is also not guaranteed that the information exchange occurs in an effective manner and that the right information is shared. Consequently, the involvement of purchasing depends on the specific project and its project members which gives a large variety from project to project. This means that past experiences of the project members play a major role in both how the information exchange occurs, and which information that is requested between purchasing and the design team. If the involvement is too low and there is no clear dialogue of each other's inputs and outputs, the design team will make assumptions of what information purchasing will need depending on past experiences. From a purchasing point of view, it may not always be that easy to know what information is needed. As shown in the Liseberg case study, see section 4.3.2, the knowledge of what information a purchaser needs are partly based on experience. If the purchaser is new in its role it can be difficult to know what information to request for a purchase. In that case that the purchaser is new in his or her role and therefore has limited experience, it becomes very important that the design manager is a more experienced person and that the dialogue and exchange of information and knowledge between the two works well. However, clearer internal processes regarding which inputs and outputs that is needed among the internal project members would facilitate and even out the variation between project and thereby ensure the same processes and a higher lowest level in all projects. These types of processes do not exist in the company today at the design level.

At NCC there exist a standardized work method, Projektstudio, which include clear guidelines in how to establish collaboration and exchange of information and knowledge between the involved disciplines during the design phase. A central part in how to establish that is to enforces the varies design disciplines to work collocated. Through Projektstudio, purchasing has a chance to be more involved during the design phase but that it not utilized fully in any of the examined projects. The collocation of Projektstudio means that purchasing works collocated with the rest of the project team at least two days a week in the project. Due to the collocation, purchasing's involvement in the design process increases since the communication with the design team becomes more continuous and spontaneous during these days. Although, purchasing does not attend to the big information sharing meeting and does not use this opportunity to become more involved in the design process. The reasons why and the approach towards the participation at the meetings differ at the two projects. The design manager at Masthuggskajen expresses that the big meetings are expensive and ineffective and prefers

smaller meetings where decisions are made. Hence, the project purchaser has decided together with the project management to not attend to the big information sharing meeting every second week to save time and money. At Liseberg on the other hand, purchasing is invited to the meeting every week and there is a wish from the design team that the purchasers will attend more frequently since questions in relation to purchasing often is being discussed. One of the purchasers at Liseberg acknowledge the benefits of attending the collocated design meetings and initially had the ambition to participate, but as in Masthuggskajen there has been shortage of time and the meetings has not been prioritized. Although, the common denominator is that the priority is made due to lack of time. Consequently, purchasing missing out on important dialogues between the design team members as well as information and discussions of why different solutions are chosen by not attending those design meetings. In the same way, the design team does not get and understanding of the needs and challenges of purchasing. Purchasing do participate in some of the following smaller working meetings during the collocation days, and there are also specific purchasing meetings. Although, in Masthuggskajen, see section 4.2.2, the participation from purchasing in the smaller working meetings is mostly in the first ones and as the design gets more detailed purchasing attend less frequently.

Specific purchasing meetings are used in both projects with focus on information sharing where the plan for all the purchases is presented, what purchases that has been made and which the next ones are. At the purchasing meetings at Liseberg, purchasing, design manager, site manager, supervisors, quantity surveyor, and project manager participates at the meeting. While, at the Masthuggskajen project it is purchasing, client represents, project manager, and site manager that participates at these purchasing meetings. Thus, there is no representative from the design team in Masthuggskajen. If there is no representative from the design team, important information can be missed out like inputs regarding technical design solutions which can be of importance for purchasing to understand why design solutions are made the specific way. This purchasing meeting could also be an opportunity for purchasing to give feedback regarding earlier purchases, if some information was missing from the design team. As mentioned in section 3.3.3, PDSA cycle is used to continually give feedback and to improve working methods. It is also stated that it is good to use in large construction projects to be able to control the costs. To use the PDSA cycle without the technical point of view and try to reduce cost in purchases, important feedback will be missed. From a purchasing and cost standpoint a purchase can initially look good but in the long run for the whole project it can increases the cost. The cost increases because the requirements that the designers have putted up might not be reached. This is something the design manger needs to bring up at the purchasing meetings and by that put in important information to be able to improve purchases with PDSA cycle. The design team may also miss important information regarding which the next purchases are, and thereby not prioritizes to finish these building documents in time.

The development of the level of detail (LOD) is a part of the design phase where it appears that purchasing partly is involved. In the early start of the projects, the VDC department defines the parameters needed in the BIM model and the LOD which is the basis for the design team during the design. When defining the parameters VDC takes inputs from, among more, purchasing. At Liseberg, it was done by discussions between purchasing and VDC regarding what and when information is needed and reviewing of objects, see section 4.3.3. It appears in both projects that the dialogue and involvement is ongoing, the

question is to what extent and how involved purchasing is in relation to what is necessary and possible.

During which stage of the design process purchasing initially gets involved is something that also varies from project to project, as mentioned in the empirical findings section 4.1.1. In both the exanimated projects, purchasing however was involved during the schematic design which is early compared to many other projects. Overall, purchasing's high workload is something that has consistently emerged throughout both projects. It has also been stated in both projects that the workload during the tender calculation phase of the schematic design is very high. That depends a lot on the use of partnering in the projects. For a partnering project, like mentioned in the Liseberg case study section 4.3.2, many consultants and installer need to be involved early in the project and therefore needs to be bought in early in the schematic design phase.

Important to have in mind when analysing the empirical findings is the delimitation of only exanimating two partnering projects. As mentioned in the empirical findings, see section 4.1.1, purchasing's involvement in the design process varies between projects and when working with partnering the involvement probably is at its highest looking at all construction projects. This is also pointed out by both the design manager and one project purchaser at Liseberg, that it is unique that purchasing is this involved in a project and in such an early stage. Many projects have probably not come this far and despite that there are improvements in these two projects, the projects are an example for those projects where purchasing is not involved in the design at all. Further on, it is important to consider that all projects are unique and faces different challenge. The findings depend on which projects that are investigated, but some parts will be similar in other projects, as seen in section 3.2.3, and can be shared within the organization. Even though the actual purchases differ between projects, the processes behind how information is shared among the involved parties should be similar and can be applicable on other projects.

5.2 The Purchaser's Influence on the Design Team and Design Process

Initially, one of the main challenges in involving purchasing earlier in NCC's project is that there are no internal processes of how purchasing should be involved in the design phase. According to NCC's core processes, purchasing firstly enter the project in the construction phase. There are already processes, but an internal movement is needed to reach a standardized way of how purchasing should be included in the design phase. In some cases, purchasing already is included partially, like at the two studied projects, but there are no guidelines on how the collaboration should look. Namely, guidelines that ensure that purchasing is involved in an efficient and structured way in the design phase. Common processes are needed regarding when purchasing should be involved in the design phase and in which forums purchasing should participate in. For instance, whether purchasing should participate in Projekstudio or not. There is also a need of processes regarding how the information should be shared between purchasing and the design team, i.e. how to secure that needed inputs and outputs between the involved parties are shared within the project team. To adapt a standardized working way in the AEC industry is not always attainable because the industry is continually moving. Every project is in some way unique and this is shown in the two case studies when calculations has been used from earlier projects. These calculations have in the end shown to not be good estimations due to that regulations have been changed and the projects where more complex than what was thought from the beginning.

From the empirical findings it becomes evident that much is about how to be effective from a resource point of view, and not considering the flow. Today it is about to plan the own job, when regarding both time and costs, as efficient as possible. If looking at purchasing not being fully included in Projektstudio, it is only about whether it is worth it or not for purchasing from a resource perspective. This can be resembled as the efficiency paradox that are brought up in the literature review in section 3.3.1. By trying to optimize a resource and reduce all work that do not bring any value to the project will create sub-optimization. In this case not attending to the big design meetings. This can create a higher workload for other disciplines or even more work for purchasing, because information is missed out and work has to be redone. Those sub-optimizations often arise because of lack in coordination between different resources. When looking in a bigger perspective at the whole project, this extra work will influence flow of information in the project by decreasing. According to the efficiency paradox it is forgotten in the two studied projects to firstly think about the flow in the project. In both projects it has been a question of time and resources, and by that reduce the total cost for the project. In the long run this will increase the workload for other disciplines in the project and by that increase the total costs of the project. If the involvement of purchasing increases, the entire flow of information may be smoother. In the long run, the project thus may gain from investing in more resources early and receive the benefit later in construction of a more reliant flow in the whole project. In both projects, it is brought up by the design managers that an extra resource in the purchasing team may not be the best solution to manage the high workload in purchasing. This because purchasing has much to do in the beginning and then the workload decreases. Due to the complexity of the projects it is hard to understand the project in that short amount of time. The extra resource may therefore have multiple purposes in the project and its phases. Although, it can be difficult to find a resource that has a broad knowledge in several of the project processes and to plan an even workload for this role. One possible alternative may be to involve supervisors earlier in the project to support purchasing since the supervisors takes over some of the purchases in the construction phase later in the project.

The interviewees were in general positive to involve purchasers early in the project, which indicates that other project most likely also would benefit from early involvement. Already in the conceptual design purchasing could provide inputs on different systems or delivery times for instance. Even though it may not be the phase when purchasing is needed the most, no one has been critical to involve purchasing early in a project. Another benefit of an early involvement is the possibility of sharing experiences, which one of the purchasers at Liseberg mentioned. The purchasers are also themselves positive to being involved early and share experiences among the project team from earlier projects. By linking project members from different disciplines together the individuals share their knowledge with the other members to evolve the knowledge creation process and innovation, as mentioned in section 3.2.3. This process cannot be made by one single discipline and purchasing needs to be involved with the design team as well to improve knowledge sharing within the team.

The early involvement of purchasing that has been made in the two examined projects has meant that purchasing had the opportunity to be more involved in the work regarding cost control. As mentioned in the literature review, see section 3.4, cost overruns are a common problem in the construction industry and managing the cost, quality, and time

parameters of the iron triangle early in a project reducing the risk of overruns. By involving purchasing earlier in the project, purchasing can be more involved in the work of finding more cost-effective solutions and material choices. An increased understanding of the client's needs will be another positive effect of an earlier involvement. By understanding these needs the opportunity of finding the right quality for the specific purchase in the specific project will increase, and thereby do more cost-effective purchases. By using target costing, see section 3.4.1, in the whole design team as a driven cost control will give the design team availability to change the design and by that reduce the cost. As mentioned in Masthuggskajen see section 4.2.3, target costing has been used but not in the extent as the project members would like to. If the reduction of costs comes from the designers instead of the purchasing the requirements that are put up will be easier to target. Due to designers has a higher knowledge level in a specific topic than purchasing do.

One part of the concept Projektstudio means that pull-planning is used for visualising of the time schedule. As appears in the Liseberg project, purchasing gets both information and tasks from the digital delivery system Apricon. However, purchasing does not add delivery notes of what purchasing needs, which is one problem brought up by the design manager. To link this with the theory behind pull-planning, see section 3.3.2, to use pull-planning as a successful tool it is important that all team members actively work with the pull-planning and updates their delivery notes. By that means that there are potential to within the pull-planning increase the purchasing involvement of the design process. If so, purchasing must start to see benefits of the whole project and not only take part of information via Apricon, but also share information and purchasing's needs to the other disciplines. For instance, when purchasing needs to have complete documents to make purchases and which information that is needed in the documents.

When looking at the social aspects and how the two projects in the empirical findings works, it is not sustainable to exclude purchasing in the big design meetings at the Projektstudio days. Projektstudio is in general a good way to coordinate and collaborate between different disciplines and consultants. By using the Projektstudio days, the employees become included and questions can easily be asked. When purchasing is not involved in the big design meetings, purchasing miss out on important information that is brought up at these meetings. As mentioned before, by including purchasing and having clear guidelines in the core processes of NCC, it would help purchasing set requirements of what knowledge they need to have. Currently, the project purchasers have to know everything about every part that is going to be purchased. By having a clear process when purchasing should be involved in the design team, purchasing would, in a social way, become more sustainable. Both projects are already working with social sustainability in the aspect of using BIM, where the level of the BIM model is adapted to the knowledge level of the design team and purchasing.

An increasement of the purchasing involvement in the design process will have effects on the whole AEC industry and not only for NCC. The understanding among the actors in the construction process will enhance, both between the contractors and architects but also to the suppliers. In order to take advantage of the benefits of involving purchasing in the designing, it requires that the entire industry talks the same language, whether it is within the same company or with other companies. As mentioned in the literature review, see section 3.5.2, the communication in the industry improves with a common language and

misunderstandings and errors decreases. In the Liseberg project it is shown that there is a language barrier between purchasing and the VDC department. If not even departments within the same company can talk the same language, it will be even harder to communicate with other companies. It is important to use the same name and notation of for instance the fire class to be able to use and find information in BIM. By using notations in a consistent is also one way to ensure that the information will be of value for the one receiving it, as seen in the literature review section 3.2.2. Consistent notations will facilitate both for purchasing to find information in BIM models, but also for the supplier to avoid misunderstanding of what to quote in the purchase. A common language will be advantageous in terms of both time, cost, and quality. Time, and thereby also costs, will be saved in not have to look for information that long when knowing how the term is defined. The quality of BIM will also increase since it probably will be less misunderstandings and the usefulness will be higher when easier being able to find all information needed.

5.3 BIM as a Helping Tool to Involve Purchasing

The AEC industry is moving towards more digital processes, which has been noted in both the literature review and the empirical findings. Purchasing has lately worked with BIM to make quantity takeoff, which is the main usage for the model in purchases at the two studied projects. However, to use the model fully in purchasing there is still a lot of work to be done. To be able to apply the model more extensively in purchasing, more information needs to be available in the model. It is often easy to add information in a model, so it is important to be precise about which information is needed. This is one aspect the are taken up in section 3.2.2, that data becomes information when it is usable for the receiver which depends on the three aspects: accuracy, timing and appropriateness. By spending consulting hours on adding information in a model that later will not be used are extra costs for the project that does not create any value. This goes against the lean method in construction where it focuses on increasing value for the customer and reducing waste, see section 3.3. Therefore, good communication and collaboration between the design team and purchasing is very important when implementing a more digital process for purchasing.

A possible consequence of making the purchasing process more digital is that the work for the design team might increase because the design team needs to add more information into the model. On the other hand, it decreases the purchasing work because everything will be collected in the model instead of in different documents. As discovered in the empirical findings, see section 3.4.1, the workload for purchasing is high, and demands a high level of knowledge about many different topics. By decreasing the work for purchasing, by working more with the model, misunderstandings can be limited in the process, which in turn reduces wrong purchases. At the end of the project, this extra work for the design team might become economically beneficial for the entire project and NCC as a whole. Whether or not the model should be used in purchases is a discussion about what is most economically sustainable. Both the short- and long-term economic benefits must be taken into account for both the projects and for NCC. This is a discussion that needs to be further investigated to determine an answer. As seen in the literature review and empirical findings, by adding information and doing more precise work early in the design phase, the long-term costs will be decreased because changes cost more the later changes are discovered, see section 3.4.1.

All interviewees in the case study do not agree about whether using the model more in purchasing will create a better product. As both the design manager and one of the project purchasers pointed out, see section 4.2.4 and 4.3.4, the model is seen as a tool. Both interviewees believed that if the tool does not facilitate the work, it should not be used just because everyone wants to move towards a more digital process. A mix of BIM models and 2D drawings would on the other hand create extra work. This is because several documents need to be checked to find the necessary parameters and those parameters are named differently in different disciplines. As mentioned in the literature review, see section 3.5.2, by using the same parameters and language in the whole ACE industry, the communication between different disciplines will be better. This also applies to the communication between the purchasing and design teams. When using a standardized method while classifying the parameters in the model, a reduction of the preparation work and better information sharing in the design phase may be obtained.

One big challenge with using BIM in purchasing is that there are few suppliers and subcontractors that do not know how to use BIM models and do not have the knowledge to find information in a model. This is something that has come up in interviews in both projects. The shift towards a more digital process has started in the design and construction phase, but a lack of using the model with purchasing can be seen at the two studied projects. If BIM models will be used more frequently by purchasing, a lot of work has to be done to educate the purchasing team, but also by educating the suppliers and subcontractors of how to use and find information a model.

6 Conclusions

The extent to which purchasing is integrated in the design phase varies from project to project. Partly, it is because there is lack of core processes regarding how and when purchasing should be integrated in the design phase, which in the current situation only exist at the construction phase. Since there are no guidelines, the integration of purchasing comes down to the individual project, its project members, and their knowledge and experiences. Thus, purchasing is more involved in the design phase in certain projects, and less involved in others. In partnering projects, the probability of purchasing entering a project in an earlier stage increases, as well as the integration throughout the design phase. Partly because consultants need to be bought up earlier, but also since collocation is more often used in these projects.

There are good opportunities for an increased involvement of purchasing in the design phase. In the work regarding Projektstudio and pull-planning purchasing is not fully involved. By utilizing these already developed working methods more the integration between purchasing and design team can increase. Increasing the involvement of purchasing in a project can affect the flow efficiency in a positive manner, instead of as today focusing on what is most efficient from a resource point of view. An increased integration of purchasing and design team means that purchasing can be more involved in the work regarding costs and finding cost-effective solutions. Furthermore, the exchange of knowledge and experiences can increase within the organization. Although, there are also challenges with involving purchasing in a greater extent. Apart from the already mentioned challenge regarding lack of internal processes that integrates purchasing in the design phase, another challenge is the language barrier both internal and external in the AEC industry. Purchasing also needs to see the overall impact of the project and how the purchasing involvement affect the other project members' work and not only how the work of a purchaser benefits.

By collecting all information in BIM instead of using multiple documents, it will be easier to find information. It applies to all parties involved in a project, and thus also purchasing which are of most interest in this thesis. A possible consequence of the increasement of models is that the purchasing work facilitates and thereby the high workload decreases. Purchasing thus gets more time to prioritize on integrating with the design team which todays is lacking due to time constraints. Although, to be able to successfully use models even more all actors need to know how to manage BIM, not only the constructors but purchasers and suppliers as well. There is also a need for a common language and a standardized way of adding parameters.

6.1 Further Research

The focus of this thesis has been limited to only investigating larger partnering projects. For further research it would therefore be of interest to examine how involved purchasing is in the design process in smaller project as well since the findings indicates a variation from project to project. The projects in this thesis has been partnering projects where aiming for high collaboration between the project members. For this reason, it is of interest to examine projects with other delivery forms. A better overall picture of the current situation will thereby be shown, partly at a company level but also within the AEC industry.

The digital maturity of the suppliers and limitations of handling BIM has appeared in the findings as a challenge of working more model based in designing and purchasing. Involving suppliers in the study would therefore be another possible further research. Partly to get a view of how the supplier experience the level of quality and information on the requests since it is the suppliers that in the end will use the information to price the purchase with the right price. It is also of interest to involve suppliers in the study in order to examine the digital level and see how confidence suppliers are in handling BIM.

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8 Appendix

8.1 Appendix 1: Interview Guide

Introduction

- A brief presentation of the master thesis
- Information about the arrangement of the interview
    - Recording and anonymity

Part 1 – Background

- What is your background in the AEC industry? (education, experiences)
- Why do you have the professional you have today?
- For how long have you been involved in the current project?
- How is your workload allocated during the project?

Part 2 – Communication Between Purchasing and the Design Team in the Current Project

- Which other disciplines do you integrate with during the design phase in the current project? (internal and external)
- How is the collaboration between purchasing and the design team in the current project?
    - Which parts do you think works good in the current collaboration between purchasing and the design team?
    - Which problems do think exists in the current collaboration between purchasing and the design team?
- How often does the communication occur between purchasing and the design team in the current project? (daily/weekly/monthly)
- Is there any information you are missing or experiencing disappears because of lack in communication?
    - If yes, why do you think this information are missing/disappears?
    - If no, how are you working for the information to not be missing/disappears?
- How involved are you in the Projektstudio days in the current project?
- How are choices in your work affected regarding costs?
- How do you work with target costing in the current project, and how involved are you in this work?

Part 3 – Use of BIM in Purchasing and in the Project

- How do you use the BIM model in the current project?
- Is the BIM model something that purchasing takes part of and is included in the development of?
- What kind of information in the BIM model do you think is necessary for purchasing to be able to use it as a basis?
- Digital procurement, which can be a possible solution in the purchasing process and means that the BIM model is used as basis for all the actors, from designers, to purchaser and suppliers.
    - Is digital procurement something that you could imagine testing in the future?
    - Do you think that digital procurement will affect the collaboration between the involved parties in the project?

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