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Digitalization and Procurement in the Construction Industry

A qualitative case study of how the BIM-model can impact the procurement process of a construction project for a Norwegian contractor

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Stian Pettersen

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Lena Bygballe

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Stian Pettersen

LIST OF ABBREVATIONS

Acronym	**Full Term**
3-D	Three Dimensions
4-D	Three Dimensions + Time Dimension
5-D	Four Dimensions + Money Dimension
BAE	Bygge-, anleggs- og eiendomsnæringen
BIM	Building Information Modeling
BMC	BIM-based model checking
CAD	Computer assisted development
GIS	Geographic Information Systems
GPS	Global Position System
ICT	Informational Communication Technology
IFC	Industry Foundation Classes
IT	Informational Technology
LOD	Level of Detail
RFID	Radio frequency identification

ABSTRACT

Digitalization has increased the productivity for many industries and contributed to change how companies interact. Construction projects are unique and consist of multiple specialized actors. The contractor coordinates the actors and is responsible for the construction to be built as agreed with the developer. There is plenty of research which describes the benefits of implementing BIM in construction projects. BIM was introduced to the markets in the early 2000s and promised to revolutionize the construction industry. Nineteen years later, the construction industry still suffers from low productivity and low margins. This paper investigates the BIM-model through a qualitative research method and aims to answer the research question: *How can the BIM-model impact the procurement process of a construction project for a contractor?* Through a literature review, three sub-research questions and a research framework have been identified. The sub-research questions and the research framework provides the basis of the discussion of literature and empirical data. A case study of a Norwegian contractor has been chosen to provide empirical data with a triangulation strategy to improve the credibility of the data collected. The research has identified critical areas for the contractor to improve before the BIM-model can impact the procurement process in a construction project. Furthermore, the paper has identified how BIM can impact the procurement process of a construction project for a contractor.

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CHAPTER 1 - INTRODUCTION

1.1 Background

The Norwegian construction industry, BAE, introduced their digital roadmap and industry vision for the year 2025 (BNL, 2017). The vision of BAE; a reduction in construction cost by 33 %, a reduction in overall delivery time from project start to project completion by 50 %, a reduction in the greenhouse gasses by 50 % and increased export of services by 50 %.

> “It is not a matter of ‘if’ the industry will be digitalized, but ‘how’.”
> BNL (2017)

The construction industry contributes to the socio-economic infrastructure and could be viewed as the most important industry leading to social and economic development (Daoud, Othman, Robinson, & Bayyati, 2018). 40% of the generated waste in the world is caused by the construction industry (Yılmaz & Bakış, 2015), where material procurement is the leading cause of material waste (O. O. Fadiya, Georgakis, & Chinyio, 2014). Construction productivity has barely increased since the 90s and is almost 30% lower than the total economy productivity (Agarwal, Chandrasekaran, & Sridhar, 2016). Construction projects have, on average, a 30% cost escalation, which is caused by long implementation phases and delays (Flyvbjerg, Skamris Holm, & Buhl, 2004).

Time, cost, and quality are the three main factors for construction management to achieve success in a project (Chan & Chan, 2004). In other words, the construction project may be regarded as successful if the building is completed within the agreed time and quality with the developer, for the calculated budget of the contractor.

Construction companies are structured as a project-based organization (Hobday, 2000). Hence, the need for external resources changes dependent on the projects. A construction project involves a range of actors which can be separated into five groups; builders, designers, regulators, purchasers, and users of the buildings (Sears, Sears, Clough, Rounds, & Segner, 2015). In this thesis, there will mainly be a focus on the builders and the designers in a construction project. Within a project, there is often a project leader with high status who controls the personnel and resources (Hobday, 2000).

Each construction project is unique, not only in the form of location and structure, but there are often different architects, engineers, contractors, and dozens of subcontractors for each project (Wegelius-Lehtonen, 2001). New technology and materials have changed building techniques and architecture. One example is the ventilation systems which has created more environment-friendly buildings, but it has also created more complex building projects (Murdoch & Hughes, 2002).

Procurement plays a crucial role in the operation of the construction supply chain (Watson, 2011) and Carr and Pearson (2002) argue that the purchasing function is an essential factor towards a company's success because it supports the company's overall strategy. Contractors purchase material and service for 70-80% of their turnover (Axelsson, Rozemeijer, & Wynstra, 2005). However, contractors tend to ignore long-term relationship and strategic partnership with their suppliers (Josephson, Polesie, & Frödell, 2009). According to literature, companies can not only purchase based on cost, but has to select suppliers and materials based on more strategic aspects (Chuan et al., 2016; Gadde, Håkansson, & Persson, 2010).

Logistics is recognized as a strategic task and could be explained as the right information about materials, quantity, place, and time (Gattorna & Day, 1986). Logistics management is one of the critical factors for a successful construction project (Otaibi, Osmani, & Price, 2013). This paper will investigate procurement because it plays a vital role in the construction project.

During the last years, development in technology has changed many industries. The impacts of digitalization have changed how society communicates and interacts. With new technological telecommunication and software technologies, the logic and autonomy of interactions can be supported by decision support systems (Leviäkangas, Paik, & Moon, 2017). There is a wide range of technology that supports the procurement process in a construction project; BIM, GIS, RFID, AR, VR, M-internet, cloud computing and big data analysis (Watson, 2011).

The construction industry is the second least digital industry and is far behind other sectors (Agarwal et al., 2016). Only 1 % of revenue is invested in information technology and research & development (Agarwal et al., 2016). The digital trend is not just a phase which will pass by. Even the construction sector of the government is focused on the digital change, such as “ByggNett” in Norway, “CORENET” in Singapore and “Planning portal” in the UK (E Hjelseth, 2015). The lack of digitalization suggests that the construction industry has much potential. According to scholars, the potentials are limitless, covering everything from the way construction is planned and to how a construction project is managed (Leviäkangas et al., 2017).

Computer-assisted development (CAD) was introduced to the market in the 1970s and is a technology which supports the representation of building elements in 3D geometry (Eastman, Eastman, Teicholz, & Sacks, 2011). Building Information Model (BIM) is based on CAD-technology and were introduced to the markets around 2000. The development from simple 3D illustrations from CAD to BIM was to seek the integration between adding information “text” to design into a functional design. BIM in the narrow sense is a digital building model and could work as a central information management hub (Eastman et al., 2011). BIM, on a broader sense, refers to a set of technologies and solutions aimed to improve inter-organization collaboration in the construction industry (Ghaffarianhoseini et al., 2017).

BIM was introduced to the construction industry as a concept for reducing cost, improving efficiency, and a tool for management (Succar, 2009). BIM could lead to a wide range of changes for the construction practice, but the rate of implementation has yet to match the benefits (Ghaffarianhoseini et al., 2017).

1.2 Motivation for the study and Research Question

The construction industry is an old industry and has impacted most people's life by providing houses, offices, and other buildings we use every day. The socio-economic contribution is enormous, yet the digitalization of the industry is far behind. Scholars believe BIM has the potential of reducing waste, increasing efficiency, and contribute with a positive impact on the industry, which is the motivation for the study. Procurement is an essential part of the construction project, and the more I researched the topic, the more interesting the subject became. By investigating how a contractor procures materials in a construction project and research the opportunities with BIM, I hope to develop an understanding as to how the BIM-model can impact the procurement process in a construction project. Based on the background of the industry, I have developed the following research question:

How can the BIM-model impact the procurement process of a construction project for a contractor?

The thesis aims to identify the importance of BIM towards the procurement process within a construction project, and based on theory and empirical data, understand how the BIM-model can impact the procurement process in projects. By this, the study will provide a contextual contribution that the contractor can take into consideration. The thesis might be limited for generalization due to a single case study, but the findings should be relevant for other contractors in the Norwegian industry.

1.3 Empirical Setting

To be able to study how the BIM-model can impact the procurement process of a construction project, the construction company Backe provides the empirical setting and is the unit of analysis. Backe has granted access to its employees, internal documents, meetings, and construction projects.

BI has a research center called "Senter for byggnæringen," where the goal is to be a competence center for the construction industry. One of the reasons I chose Backe is because they are one of the partners of the research center "Senter for byggnæringen." Furthermore, Backe is open to new ideas and let students gather valuable information for their thesis. Backe is a forward-thinking company which works toward digital solutions. Backe just started a research group cooperating with BI, Lean Communications, and SINTEF, where the goal is to digitalize the whole construction process (Aarhus, 2018).

Backe was founded in 1946 by Gunnar M. Backe and is still a family-owned company. During the last years, Backe has acquired and partnered with companies and grown to be one of Norway's biggest construction companies. The revenue in 2016 was 3710 million NOK, and the company had 882 employees. Backe consists of several subsidiaries and operates within four main business areas: project development, property management, rental of machinery, and contractor. Backe Entreprenør AS is the contractor division of Backe hereafter called Backe and will be the unit of analysis. The contractor division consists of ten local subsidiaries in different regions, and corporate governance is structured such that each region is self-managed. Three of the subsidiaries will be used as sub-cases for the study.

> *"All our subsidiaries have a strong local anchor and are managed by local employees. We prefer that way because we believe it is the best."*
> (Backe, 2018).

The purpose of this research is to develop theory; therefore, it is essential to select a unit of analysis which will provide theoretical sampling (Eisenhardt & Graebner, 2007). Backe will provide the research with an empirical setting for theoretical sampling. After discussion with Backe, they recognized the research question as important and offered an internship for two months to work with the research. The internship provided the research with unusual research access and detailed empirical description of the procurement process in a construction project. Three sub-cases – three projects – was chosen for data collection. Three subsidiaries provided one project each, where the projects differ in value size and buildings types. The value size of the project varied from <100 million NOK to <500 million

NOK. The projects were, however, in the same project phase. All three projects had just started with the construction. The three construction projects gave the research insight into different practice across Backe and gave broader empirical data of the dynamics in construction projects.

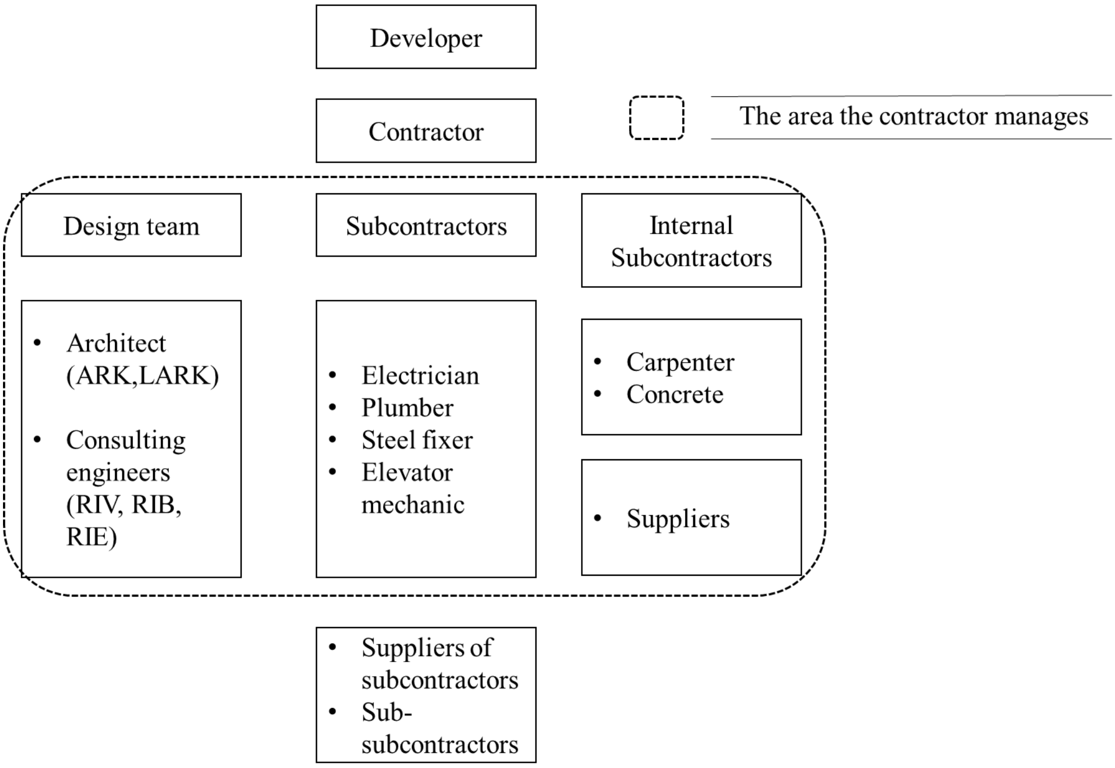


Figure. 1 Illustration of the project hierarchy. The circle shows whom the contractor manages.

The contractor and the design team create the production foundation for the project. The subcontractors fulfill their part of the project based on their trade competence. The subcontractors handle their material procurement, and the contractors only manage the workflow of the subcontractors. All three projects subcontracted the production of the carpentry and concrete in-house. This means that Backe is responsible for the production of carpenter and concrete in the construction project. Therefore, the suppliers chosen to provide empirical data is a supplier who mainly contributes to products related to the production of the carpenter.

1.4 Structure of The Paper

There are six chapters in the paper. The first part of the paper is an overview of the theory. There are four main topics from the theory which describes the construction industry and theoretical views of the topics. The theoretical part is divided into the contractor organization, relationships, planning and procurement, and digitalization & BIM. At the end of the literature review, there is a discussion of the literature, which results in three sub-research questions and a research framework. Chapter three describes the methodology used for the research. The methodology includes why the research design and strategy are chosen, data collection, the analytical process, and the scientific quality. The fourth chapter presents the empirical findings and analysis. The empirical data, discussed with the sub-research questions, provide the practical explanation of procurement in construction. The fifth chapter discusses the literature and empirical findings. The paper ends with a conclusion where practical implications are suggested, and future studies are recommended.

CHAPTER 2 - LITERATURE REVIEW

This chapter will examine the relevant theory based on the research question: *How can the BIM-model improve the procurement process of a construction project for a contractor?* There are four topics investigated in the literature review, namely the contractor organization, the relationships of the contractor, the planning and procurement process, and digitalization and BIM. The review of the literature and theoretical framework from these topics will provide a broader understanding of what other scholars has found in their studies. Besides, the review will allow for a better understanding of the industry. Also, the literature review will provide insight into the practice of contractors from different parts of the world. The end of this chapter will discuss the reviewed literature and result in three sub-research questions. The sub-research questions will be used as a guide for the empirical analysis and allow the empirical analysis to address critical factors form the literature. The sub-research questions will help to answer the main research question.

2.1 Contractor organization

A general construction contractor is a project-based organization who sets the boundaries for the building projects (Hobday, 2000). The definition of a construction contractor is a company that organizes the building of houses, offices, schools, and other related constructions by supplying materials and work for a building project (Dictionary, 2019). There are several classifications of contractors, and this literature review will focus on housing contractors. The following clarification of contractors basing on the book "Construction project management" by Sears et al. (2015). Contractors separate into specialty contractors and general contractors. General contractors assume broader responsibility for the project and have direct contact and contract with the developer. The general contractor assigns the specialty contracts, also called subcontractors, such as electricians and excavation, for the construction project. The general contractor is responsible for the construction project to be completed within the timeframe, and budget agreed with the developer.

Construction is a highly complex industry due to the high number of actors involved (Gidado, 1996). There are different approaches to deal with this complexity (Cox & Ireland, 2002; Vrijhoef & Koskela, 2000). A construction company working as a contractor will organize their projects as a project-based organization with a project team. The reason for a project-based organization is because it is suited for managing complexity with cross-functional business expertise (Hobday, 2000). Further, Hobday (2000) explains that the primary business mechanism for a project-based organization is to coordinate and integrate all the main business functions of a firm, so, the project will be carried out within the boundaries of the contractor through the project team.

Gann and Salter (2000) emphasize that the project teams have limited contact with senior management, are based off-site and work in teams with subcontractors. It means that the project teams generate profits and value outside of the main office for contractors. The project-team consist of both internal employees and external subcontracted companies. The internal project-team that is assembled typically consists of a project leader, production manager, and a construction site manager (Sears et al., 2015). The construction industry is a highly knowledge-based industry which relays on the knowledge of the project-team (Carrillo, Robinson, Al-Ghassani, & Anumba, 2004).

The construction industry has long entrenched traditions, and projects are often approached conservatively in process terms (Ireland, 1996). In addition to this, each actor looks at the construction process from their point of view. Therefore, it is essential that the internal project team can manage the actors in the construction project. Furthermore, there is often limited process knowledge sharing between projects (Newell, Bresnen, Edelman, Scarbrough, & Swan, 2006). The process does not change because the accumulation of the project team's knowledge comes from past projects, and the contractor will not add any short term cost for improvements (Newell et al., 2006). There is a lack of process improvement because project process usually represents non-routine features, which means non-systematic repetition. Non-systematic repetition is a process which is hard to improve because the process is not standardized (Gann & Salter, 2000). This complex collective process involves a multiplicity of specialized actors which the project leader needs to coordinate (Carrillo et al., 2004; Ebers & Maurer, 2016). The relationships between the contractor and suppliers and the details of the procurement process will be elaborated in the following sections.

2.2 Contractor, subcontractor, and supplier relationships

To what extent a general contractor chose to subcontract work depends on the project complexity. The general contractor can let the entire job be done through subcontractors or by its own company, but the main objective for the general is to finish the project within the time agreed with the developer (Sears et al., 2015). The work of the contractor is to provide supervision, job coordination, and project billing.

In order to handle all the different suppliers and manage the complex process, the construction industry have had fragmented approaches towards relationships where design separate from production and involvement of suppliers often have been postponed and not included before later in the project stages (Bresnen & Marshall, 2000; Chan, Chan, & Ho, 2003; Egan, 1998). Fragmentation of the process was ideally created to manage the complex process. However, this has led to complicated contractual relationships and discontinuity of teams (Dainty, Briscoe, & Millett, 2001; Fulford & Standing, 2014).

When the contractor chooses subcontractors, it is often based on competitive bidding, where the lowest bidder gets the contract (Wegelius-Lehtonen, 2001). One reason for selecting the lowest bidder could be due to a high number of subcontractors. In large projects 80-90% of the work is done by subcontractors (Hartmann & Caerteling, 2010; Ireland, 1996), there could be up to 100 separate subcontractors in large projects (Ireland, 1996). The construction industry is characterized as a highly specialized industry, which is the reason for the high number of subcontractors (Manning, 2017). Most of the major contractors in Norway have concrete and carpentry in-house while they use subcontractors for other disciplines. Scholars agree that companies can not only select suppliers based on cost, but have to select suppliers based on more strategic aspects (Chuan et al., 2016; Gadde et al., 2010).

Contractors tend to ignore long-term relationship and strategic partnership with their partners (Josephson et al., 2009). There are good examples of a strategic partnership between the client and the contractor, which has led to considerable improvement in project delivery (Barlow, Choen, & Jashapara, 1997; Bennett & Jayes, 1998). There has, however, not been the same partnership throughout the supplier network (Dainty et al., 2001). Historically, the relationship between the general contractor and the subcontractors used to be very hierarchical (Eccles, 1981).

Change of partnership and projects composed of a new set of partners will limit opportunities for the economics of standardization, knowledge transfer and will not benefit from the learning curve (Brady & Davies, 2004; Gann & Salter, 2000; Schwab & Miner, 2011). However, there could be benefits from changing suppliers because partner flexibility can create new learning opportunities (Schwab & Miner, 2011).

In order to handle the complexity, and move away from a fragmented process, O'Brien, Formoso, Ruben, and London (2008) suggest the construction industry should have more supply chain management focus. A supply chain is a collection of partners working towards a common goal, connected through financial, informational, and service flows (Fugate, Sahin, & Mentzer, 2006). Processes like demand, design, material requirements planning, product delivery, and subcontractor management can be improved significantly through supply chain management (O'Brien et al., 2008; Saad, Jones, & James, 2002). To improve the performance of the construction industry, scholars suggest integrating business processes and follow the principles of supply chain management (Briscoe & Dainty, 2005; Ekeskär & Rudberg, 2016; Vrijhoef & Koskela, 2000).

Supply chain management is considered problematic for the construction industry (Briscoe & Dainty, 2005; Fearne & Fowler, 2006; Fernie & Thorpe, 2007). Supply chain management is problematic because construction relationships being arm’s length and adversarial (Briscoe & Dainty, 2005). Arm’s length and adversarial relationships are a result of traditional construction procurement practices (Briscoe, Dainty, Millett, & Neale, 2004). Even if Saad et al. (2002) surveyed of the construction industry showed that the practitioners scored long-term and close relationships as being an essential factor, the practitioners indicated their unwillingness to rationalize their suppliers, establish common purpose, exchange information openly and share learning.

Suppliers are an essential resource for the contractor, and there should be better collaboration in the supply chain in order to improve project efficiency concerning time, cost, and quality. There has been a move towards more strategic relationships, collaborative agreements and some integration between supply chain actors (Akintoye, McIntosh, & Fitzgerald, 2000; Briscoe & Dainty, 2005; Holti, Nicolini, & Smalley, 2000; Rimmer, 2009), still, studies show that the construction industry needs to reconsider its approach for supply chain relationship (Cox & Ireland, 2002; Pryke, 2009).

Fulford and Standing (2014) concluded, based on their case study, that the construction industry lacked the “Strength” needed for creating a relationship based on trust and shared values. Using their matrix (Appendix 1), the contractor should distinguish suppliers based on relationships- requirements and capabilities when determining how invested the company should be with the suppliers. Furthermore, they recommend better project management through standardization, better information flow, and investment in IT as implications for better collaboration in the construction supply chain. Productivity improvements are achieved through improved financial management and better communication and integration with supplier IT systems. IT-enabled communication would reduce errors, cost, and time overruns in projects and increased knowledge carried to future projects (Fulford & Standing, 2014). A stronger relationship-tie with suppliers will increase obligation and accountability from suppliers, which will improve the quality of the project. ICT integration will impact time, cost, and quality through better supply chain development (Fulford & Standing, 2014).

A case study by Frödell and Josephson (2008) showed that one of the greatest strength identified in the relationship between the contractor and one its biggest suppliers were the competence for the products the supplier brought to the projects. They also found insufficient demands from the contractor which the supplier handled in a flexible and divergent way to fulfill the project. Frödell and Josephson (2008) conclude that the total cost of relationship could be decreased if the contractor would reduce their uncertainty of demand and not have short notice orders.

The next section will clarify the planning and procurement process of a contractor within the interaction between contractor, subcontractor, and supplier.

2.3 The planning and procurement process

Norwegian contractors have different forms of enterprises that determine the contracts between the developer and the contractor (byggkvalitet, 2019). The form of enterprise will impact the responsibility and risk for the contractor. Therefore, the enterprise will affect the planning stage of a construction project. Since the enterprise form affects the planning stage, the scope of this literature will ground on the form of an enterprise called "totalentreprise" or turnkey contract. In the turnkey contract, the contractor undertakes to carry out the design, planning, and execution of the contract with the developer. The contract is typically based on an architect work, which is the fundament for the construction project.

Every construction project could be viewed as a prototype because there are never two similar projects. Each project has a different design, site, and there are different internal team assembled for the project, different architects, mechanical engineers, construction contractor and a dozen of different subcontractors (Ireland, 1996; Wegelius-Lehtonen, 2001). Going from an initial plan of a building to a tangible office or house, the construction process typically consists of several project phases and stages.

The following description of the project stages is based on the book "Construction Project Management" by Sears et al. (2015). The first stage is the planning and definition where the developer creates the conceptual aspects of the project and simple architectural design. This stage is typically done before choosing the general contractor and results in the basis for the turnkey contract. The second stage is the design phase, which involves the architectural and engineering design of the project. The contractor assigns engineering consultants and works with the developer and the architect to create a more specific construction project. Production information can be added to a digital platform, resulting in a Building Information Modeling (BIM) model of the project. The BIM-model contains digital information from the design stage and can be used for project management. The third stage is the procurement and construction stage. In practice, the design, procurement, and construction are overlapping phases, where the design stage is not necessarily final before the construction starts. The procurement process in construction projects includes all activities related to providing goods and services necessary to accomplish the project objectives (Ruparathna & Hewage, 2015; Sears et al., 2015). Construction refers to the process of physically build the project, providing the workforce, equipment, suppliers, and management needed to accomplish the project.

Project planning is typically done with a Gantt chart, which describes, the number of employees and length of time needed for the activity (Taxén & Lilliesköld, 2008). However, scholars argue that this type of project planning is too static and becomes unmanageable in more complex projects (Milosevic & Martinelli, 2016; Taxén & Lilliesköld, 2008). Planning the procurement and construction phase is difficult because there are many organizations involved from a range of industries in the project-specific tasks. The project-specific tasks separate into planning and design, engineering, supply and integration, installation of materials and components, and complex technical systems (Gann & Salter, 2000), which all are managed by the leading contractor.

The objective of the procurement process is to provide materials at the site in time with the project schedule, materials with the right quality, in the right quantity, at the right price from the right source (Chitkara, 1998). The procurement process is the subsequent phase of the design phase (Yeo & Ning, 2006); therefore, the delivery of products and services requires collaboration between all the firms involved. The procurement process can impact both the cost of a project and the environment (Ruparathna & Hewage, 2015). The uniqueness of each project leads to lack of process improvement by the project team (Gann & Salter, 2000).

The general contractor is responsible for the procurement process, which includes sourcing, purchasing, contracting, and on-site material management (Habibi, Kermanshachi, & Safapour, 2018; Nethery, 1989). Traditional procurement methods have focused on the lowest price, not the best value, which is seen as a significant weakness for traditional procurement methods (Hall, 2010; Hampton, 1994; Walker & Hampson, 2008). There are several reasons why the lowest price focus is a major weakness. One reason why the lowest price is a weakness is that the total cost can increase when the contractor or project owners need rectification of impaired quality of the construction (Walker & Hampson, 2008). Another cost driver for projects is the unavailability of resources, which can cause severe implications for the project such as time delays (Kermanshachi, Dao, Shane, & Anderson, 2017; Sambasivan & Soon, 2007).

A study by Sambasivan and Soon (2007) shows that material-related causes are ranked the second highest category for causing delays in construction projects. When there were time delays in the construction project, the scholars found that the developer blamed the contractors improper planning and labor supply, while the contractor blamed the developer slow decision making. However, improper planning and site-management are the leading causes of project delays, which both are controlled by the contractor (Sambasivan & Soon, 2007). A quantitative study by Al-Momani (2000) shows that factors as designers, developer change, weather, site conditions, and late deliveries were causing delays for the construction project. These findings are in accordance with the findings from Sambasivan and Soon (2007). Irizarry, Karan, and Jalaei (2013) emphasize that there is limited research on models which deals with the entire process of construction supply management. Construction supply management starts with the design decisions which impact cost and time, ending with monitoring and inspection on construction site.

There is significant awareness of the importance of supply chain management in the construction industry (Saad et al., 2002). Moving from the traditional single-stage procurement towards the adoption of supply chain management can help the construction industry overcome its fragmentation and adversarial culture, and better integrate its processes (Saad et al., 2002). Boundary management is one way for the construction industry to get more control when managing the project activities

(Fellows & Liu, 2012; Ruuska, Ahola, Artto, Locatelli, & Mancini, 2011). Boundary management refers to managing the necessary activities between multiple parties in order to carry out the task at hand (Fellows & Liu, 2012). Boundary spanning technology could lead to better collaboration between the stakeholders in a construction project (Cox & Ireland, 2002; Shen, Chen, & Lu, 2008).

Various IT systems have been used in the literature as ways to improve supply chain management in construction. Such IT systems have focused on the development of integrating the supply chain process to support the planning and coordination, time, and storage of materials, transportation and logistics optimization (London & Kenley, 2001). IT-systems has improved supply chain management for many industries. When companies want to improve their supply chains integration, Williamson, Harrison, and Jordan (2004, p. 383) concludes

> "*The more integrated the effort and the more virtual the supply chain, then the larger the potential benefits. However, the further upstream and the more integrated the supply chain focus, the more time consuming and complex it is to achieve*".

Material management includes functions such as materials planning, purchasing, inventory control, warehousing, material transportation, and handling at the site (Chitkara, 1998). Material management and procurement includes many of the same functions and will, therefore, be cross-referenced. Material planning is closely linked to project planning. To limit the thesis, there will be a focus on purchasing and site-management within procurement and material management. There will be a focus on purchasing and site-management because these can impact the time delays in a construction project.

2.3.1 Purchasing

Weele (2014, p. 3) define purchasing 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 and managing the company's primary and support activities are secured under the most favorable conditions."*

From the definition of Weele (2014), it is clear that the purpose of purchasing is to supply all materials and services needed for the construction project which are necessary to complete the project. Purchasing could be separated into internal integrated purchasing and external integrated purchasing. Internal integration has to as the interaction between the purchasing department and the projects, and external integration is the interaction between the purchasing department and the suppliers (Frödell, Josephson, & Koch, 2013). This thesis will focus on the external purchasing between the contractor and the suppliers.

Purchasing is important for the construction project because contractors purchase materials and services for 70-80% of their turnover (Axelsson et al., 2005). As soon as the design phase has progressed sufficiently, the detailed purchasing specification can be drawn (Sears et al., 2015). The detailed purchasing specifications are managed through the material plan. The construction material planning involves estimating quantities, identifying material requirements and defining specifications, locating sources for procurement and schedule the purchasing to ensure a smooth flow of materials concurrent with the project schedule (Chitkara, 1998). The purchasing of materials and equipment is often done by a purchasing department or the project manager. The project manager is always responsible for the details of the purchase, which should include a delivery date based on the project schedule (Sears et al., 2015; Yeo & Ning, 2006).

Before the planning of material supply to the construction site, there needs to be a material plan. The material plan is clarified between the client and the contractor and should define the materials required for the stages, from which supplier and time for delivery (Chitkara, 1998). The process of choosing materials is done by inviting vendors to give quotations. The quotations are analyzed for the price, delivery timings, and payment terms by the project leader. The materials chosen by given suppliers will be put in the material-plan (Chitkara, 1998).

Findings from a case study by Osawaru et al. (2018) showed that 75% of construction sites encountered delays due to untimely deliveries. However, 80% of construction sites places the orders for materials between one and two weeks of the requirement day. The scholars highlight that late ordering of materials my result in delays and recommend a prompt ordering of materials from local suppliers when possible.

2.3.2 Site management and logistics

The objective of logistics in a construction project is to coordinate the delivery of materials and resources in order to meet the required availability to secure the workforce productivity (Caron, Marchet, & Perego, 1998). Sullivan, Barthorpe, and Robbins (2011) state that construction logistics could be separated in a bundle of tasks: mobilization and resourcing of the logistics team, materials delivery, and handling, transport and communication are some of the tasks. Construction logistics involves the handling of materials, transportation, and distribution of resources, strategic storage on- and off-site and planning of building site layout.

Project planning is necessary to coordinate logistics scheduling. Planning the delivery of material to construction sites need to be coordinated in order to meet the 'required availability' (Caron et al., 1998). If the material is not available when it is needed, there will be costly delays (Caron et al., 1998; Sullivan et al., 2011). Logistics affects workforce productivity and could be viewed as one of the most critical activities within construction. However, contractors are often competing on bidding, where price and technical specification are the primary basis, but the process terms are not assessed (Ellis Jr, 1993). Poor logistics management has resulted in high amounts of waste for the construction industry (Omar & Ballal, 2009). Few construction companies have implemented logistics management (Said & El-Rayes, 2014), one reason could be the lack of standardized digital information and the need to integrate a large amount of material data (Sargent, 1991). Rebolj, Babič, Magdič, Podbreznik, and Pšunder (2008) suggested a focus on information delivery for improving the construction logistics, which will result in better productivity, avoiding delays, and reducing waste. A challenge for logistics management is to link site-logistics with supply logistics (O. Fadiya, Georgakis, Chinyio, & Nwagboso, 2015).

Logistics management have the potential to reduce the amount of deliveries to the construction site, reduce cost of labor, reduce time of labor, waste of materials and increase efficiency (Agapiou, Clausen, Flanagan, Norman, & Notman, 1998; O. Fadiya et al., 2015; Otaibi et al., 2013; Sullivan et al., 2011). A construction project could become more efficient if site-logistics and supply logistics are integrated (Ying, Tookey, & Roberti, 2014). Improving the connection between site-logistics and supply logistics could be done through information technology (J. Song, Haas, & Caldas, 2006; Sundquist, Gadde, & Hulthén, 2018).

Logistics in construction have been approached by many scholars, where the focus has been reversed logistics (Shakantu, Muya, Tookey, & Bowen, 2008), minimizing material logistics cost through project management (Choudhari & Tindwani, 2017), logistics strategy (Fraser, Haig, Heduan, & Limna, 2017), methodology for logistics planning on construction site (X. Song, Xu, Shen, & Peña-Mora, 2018) and construction risk management with BIM (Musa, Abanda, Oti, Tah, & Boton, 2016). However, few studies have examined how BIM could impact construction logistics management (Whitlock, Abanda, Manjia, Pettang, & Nkeng, 2018). The literature on digitalization in the construction industry with a focus on the development of BIM is discussed in the next section,

2.4 Digitalization & BIM

The construction industry has been a laggard in digitalization, compared with other industries (Agarwal et al., 2016; Friedrich, Le Merle, Grone, & Koster, 2011). The reason for the low digitalization in the construction industry can be due to the high degree of on-site interaction, low affinity for digital technology among the labor pool and fragmented relationships (Friedrich et al., 2011; Leviäkangas et al., 2017). The spend on information technology accounts for less than 1 percent of revenues in the construction industry (Agarwal et al., 2016; Leviäkangas et al., 2017). A study by Leviäkangas (2016) showed that there is a correlation between investment in digitalization and labor productivity. BIM is an IT-technology, and is viewed as the symbolization of digitalization (Leviäkangas et al., 2017), and, there is a global call for the use of BIM technologies in the construction industry (Ogwueleka, 2015).

2.4.1 Building Informational Modeling

Building Information Modeling (BIM) is defined by international standards as mapped information about the life cycle of the construction, whereas BIM intends to

> *"facilitate interoperability between software applications used during all stages of the life cycle of construction works, including briefing, design, documentation, construction, operation and maintenance, and demolition. It promotes digital collaboration between actors in the construction process and provides a basis for accurate, reliable, repeatable, and high-quality information exchange* (Standard, 2016).

The BIM-model consist of different Industry Foundation Classes (IFC)-files created by the different disciplines, likes architects, constructional consulting engineers, electrical engineers, and others. (Eilif Hjelseth, 2015). BIM can be separated into different dimensions. The dimensions of BIM are 3-D (virtual model with quantity), 4-D (simulate the time), 5-D (cost estimation) and 6-D (finished construction) (Eastman et al., 2011). The dimension of the BIM-model is dependent on two factors, namely the information level of the model and software technology. The information level of a BIM-model is often referred to as the level of detail (LOD) (Gröger, Kolbe, Czerwinski, & Nagel, 2008). Examples of information in the BIM-model can be geometry, spatial data, specifications, aesthetics, thermal- and acoustics properties (Agarwal et al., 2016). It means that a BIM-model is an information hub. In order to exploit the dimensions of the BIM-model, there is a need for software technology (Eilif Hjelseth, 2015).

2.4.2 Current benefits from BIM

BIM has innovated the process of production and management of construction, and, provides the opportunity to virtually simulate the processes before the physical start of the construction (Whitlock et al., 2018). This virtual simulation is what scholars have termed as "digital twin" because, in theory, you build the construction twice, once virtually and once physically (Grieves, 2014). By having the possibility to build the project virtually, the BIM-model could change the planning process. The BIM-model can add levels of accuracy by calculating the quantity and quality of the planning process (Zhang, Zayed, Hijazi, & Alkass, 2016). Also, BIM opens access to real-time information sharing for all parties in a construction project.

If the use of BIM is appropriately implemented, projects gain substantial advantages in coordinating design and construction sequence through the BIM-model (Staub-French & Khanzode, 2007). Further, the use of BIM can provide technical benefits (Lee, Sacks, & Eastman, 2006; Son, Lee, & Kim, 2015; Succar, 2009, 2013), knowledge management benefits (Döllner & Hagedorn, 2007), integration benefits (Bryde, Broquetas, & Volm, 2013; Cooke & Williams, 2013), economic benefits (Lee, Park, & Won, 2012) and scheduling benefits (Eilif Hjelseth, 2015; Johansson, Roupé, & Bosch-Sijtsema, 2015).

2.4.3 Information exchange with IFC

The digital representation of the construction project enables collaboration in a multidisciplinary team through the transfer of digital data and specifications between different software applications (Ghaffarianhoseini et al., 2017). Information like geometry, light analysis, geographic information, fire rating, U-values and spatial relationships provides comprehensive information of the construction project, which can be stored in the BIM-model (Ghaffarianhoseini et al., 2017). The information provided in the model is a result of inputs from various professionals. BuildingSMART created the file format standards for the exchange of data. The standard file format for construction objects is called IFC (Hietanen & Final, 2006). The standard was created in order to secure cooperation between the users of the BIM-model, and, to secure the development of software technology with standardized data (Hietanen & Final, 2006). A study by Lin et al. (2013) shows that cooperation with IFC-files is accurate and provides rich data for the BIM-model. However, the elements in the IFC-files needs rich information and description to provide value for collaboration.

From Irizarry et al. (2013) research, we find that the objects in the IFC-files need to be defined with geometries and contextual information to be of value for procurement.

> *"In order to have the right resources in the right quantities (at the right place) at the right moment while minimizing costs and rewarding all parties involved in managing logistics, supply chain information systems require a great deal of data input."* (Irizarry et al., 2013, p. 244)

Further, the scholars emphasize that objects in the IFC-file can have a name such as "ifcTypeObject," therefore, if the parties do not agree upon the object names, the BIM-model would not provide the required information.

2.4.4 Decision making with BIM

The BIM-model provides a collaborative platform for the stakeholders in the construction project and facilitates an integrated approach for information about design and construction (Bryde et al., 2013; Ghaffarianhoseini et al., 2017; Eilif Hjelseth, 2015). Complex construction projects demand many decisions. Scholars argue that Information Technology (IT) and Information Communication Technology (ICT) can provide better decisions by evaluating multiple attributes (Zavadskas, Turskis, & Tamošaitiene, 2010). By evaluating multiple attributes, the project developers, designers, contractors, subcontractors, and construction managers can use the BIM-model as a boundary tool for decision making. A study by Suermann (2009) shows that employing BIM in the design phase had a positive impact on the construction phase. Implementation of BIM resulted in improved coordination, increased design confidence, conflict detection, and simplified phasing.

2.4.5 BIM-based model checking

BIM-based model checking (BMC) is "*software which processes the content of information in BIM-files according to rules specified as pre-defined procedures.*" (Eilif Hjelseth, 2015, p. 2). BMC is widely used in the Norwegian construction industry. It is used during all the construction phases and used for clash detection, coordination of different model files (disciplines), coordination of project solutions, information and quantity take-off and calculation of material and work (Eilif Hjelseth, 2015). BMC is used when controlling the BIM-model, and to make sure it is possible to build physical construction, which is called clash control. The level of information the BIM-model contains, i.e., the LOD, will determine the value of the clash control. Eilif Hjelseth (2015) emphasizes the difference between a model with a high degree of information and low degree of information, because, the degree of information will determine the number of issues in the BIM-model, and how important they are, with the clash control. The degree of information will impact what level of compliance and content checking, which is possible with the BMC (Appendix 2).

BMC is used for coordination of the project team. With the clash detection, the project leader will use the issues found in the model to coordinate changes for the BIM-model (Eilif Hjelseth, 2015). With the information and quantity take-off, the project leader can estimate the procurement plan for the calculation of material and work. However, sparse modeling in the BIM-model will influence the result. An example from Eilif Hjelseth (2015) study shows that a stair was modeled as many small slabs, which then influenced the quantity take-off. The slabs influenced the quantity take-off because the slabs were estimated as concrete, and not as stairs. The sparse modeling of stairs shows how important the quality of the BIM-model is when utilizing software tools.

Even if the Norwegian construction industry has a high degree of BIM use, Eilif Hjelseth (2015) point out that very few people had the knowledge to use the related software, and, BMC was looked at as a specialist tool, operated by a limited number of users in projects. Further, the scholar emphasizes this as a paradox because the software is easy to operate. In addition to the lack of competence, lack of relevant information in the BIM-model and low BIM-maturity in companies are reasons for limited use of BMC in construction projects.

2.4.6 Supply chain management with BIM

The term supply chain in construction refers to the stages which construction resources, such as materials, equipment, and personnel, proceed from supply point to the construction site (Irizarry et al., 2013). Implementation of IT-systems has been suggested for improving the efficiency of material planning and delivery on the construction site (Omar & Ballal, 2009). Tserng, Yin, and Li (2006) developed an IT-tool to optimize the inventory holding cost for the supply chain, which can improve the construction material management. The scholars stress the fact that if only one of the actors in the supply chain optimizes their inventory holding cost, there will be an increased cost for the whole supply chain. Grilo and Jardim-Goncalves (2011) research on e-procurement in the construction industry revealed that the BIM-model was not mature enough for e-procurement. BIM could provide the quantities. However, to organize the elements in the BIM-model to be used for tender is a rather complex issue. The complex issue is related to aggregate the products and services that are released to tendering quotations (Grilo & Jardim-Goncalves, 2011).

By integrating BIM and geographic information systems (GIS), it is possible to keep track of the supply chain status and provide information about the delivery of materials to the construction site (Irizarry et al., 2013). Integration of BIM and GIS requires information input from the supply chain, and the output will provide valuable information for decision making in the construction project (Appendix 3). Irizarry et al. (2013) purposed model provides the opportunity of evaluating the availability of resources and supplier's distribution in the design phase. When the design decisions are made, it is possible to do a complete cost analysis of the suppliers, where transportation, inventory, and delivery cost is evaluated. Then, tracking of resources and a visualization of the logistics pattern helps the site management to keep control of the actual delivery against the planned delivery.

However, there are some limitations to their application. The method requires a lot of information input in order to provide valuable information output. First, when modules and products are defined with properties and parameters, there needs to be a universal language and standardized method (Gröger et al., 2008). When modules are not defined with properties and parameters in a standardized way, the software tool cannot provide the right information. Moreover, if data cannot be extracted from the BIM, manual entry of the data is needed.

Furthermore, if there is a lack of information, Irizarry et al. (2013) say the model could not provide information. For example, if the logistics cost is not available, the total cost of the supply chain will not work. GIS needs dynamic and instance location information from storage technologies, such as RFID or GPS. Therefore, the suppliers of the contractor need to provide this technology on their materials. If the supplier does not provide this technology, the location of the materials will not be available for the project team. The scholars emphasize that these software-tools require the user to know about both systems and their functionalities in order to use the model for project management and improvement for the construction project (Irizarry et al., 2013).

Further, Ghaffarianhoseini et al. (2017) concluded that the most significant reasons why the construction industry not has adopted BIM include the lack of demand, cost, and interoperability issues. The scholars explain the low value to difficulty ratio is caused by the lack of software interoperability and non-user-friendly format combined with a project team who does not have the skills or experience.

> *"Successful BIM adoption requires significant investments by AEC firms, including investment in software, hardware, training, and other requirements."*
>
> Ghaffarianhoseini et al. (2017, p. 1050)

2.5 Discussion of literature

Based on the research question, *"How can the BIM-model improve the procurement process of a construction project for a contractor?"* there has been a review of the literature. The literature has covered the topics of the contractor organization, the relationships between the contractor, subcontractors, and suppliers, the planning and procurement process, and digitalization & BIM. To understand how BIM-model can impact the procurement process of a construction project for a contractor, we need to understand the process of the construction. To connect the literature, I will start to discuss the procurement process, then I will discuss the design phase, the contractor organization, and then finish the discussion with the relationship of the contractor.

Construction refers to the process of physically build the project, providing the workforce, equipment, suppliers, and management needed to accomplish the project. In a construction project, the procurement process includes all activities related to providing goods and services necessary to accomplish the project (Ruparathna & Hewage, 2015; Sears et al., 2015). The objective of the procurement process is to provide materials at the site in time with the project schedule, materials with the right quality, in the right quantity, at the right price from the right source (Chitkara, 1998). It is clear that the procurement process will impact the construction process. Sears et al. (2015) state that the design, procurement, and construction are overlapping phases, where the design stage is not necessarily final before the construction starts. Project planning is based on the designed construction. Project planning is typically planned with a project schedule based on a Gantt chart (Taxén & Lilliesköld, 2008). The project schedule describes the number of people and time needed to complete the activity. Projecting with Gantt chart has been criticized for becoming unmanageable as a scheduling tool (Milosevic & Martinelli, 2016). The construction project is complex and involves a multiplicity of specialized actors which the project leader needs to coordinate (Carrillo et al., 2004; Ebers & Maurer, 2016). BIM provides innovation for the production and management of construction (Whitlock et al., 2018). The BIM-model can add levels of accuracy by calculating the quantity and quality of the planning process (Zhang et al., 2016) and provides the opportunity for real-time information sharing. However, BIM-model must be appropriately implemented. The implementation starts in the design phase of the construction.

2.5.1 Design phase and BIM

The objective of the contractor is to fulfill the contract with the developer. In order to do this, the contractor undertakes to carry out the design, planning, and execution of the construction project, based on the contract with the developer (Sears et al., 2015).

According to Sears et al. (2015) after the planning and definition stage, the contractor assigns engineering consultants and work with the developer and the architect to create a more specific construction project, which is referred to as the project team. The project team can add production information to a digital platform in the design phase, resulting in a BIM-model of the project (Sears et al., 2015). The decisions made in the design phase are essential, because, the contractor will start the project planning based on the agreement from the design phase. Therefore, detailed construction requires much collaboration between the project team. IT-technology can provide better decisions making for the project team because the technology can evaluate multiple attributes if appropriately implemented (Zavadskas et al., 2010).

With BMC, the project team can control the BIM-model for clash detection and agree upon the details of the construction project (Eilif Hjelseth, 2015). However, the level and quality of the information will determine how valuable the BMC is. By looking at the information flow (appendix 3) required for the integration of BIM and GIS, it is clear that much of the information is provided in the design phase. Irizarry et al. (2013) emphasize that using the BIM-model for supply chain decisions requires information from the design phase in order to use it for the construction phase. Integration of the supply chain is time-consuming but can result in significant benefits (Williamson et al., 2004).

There seems to be an agreement from the scholars that there are plenty of benefits from the implementation of BIM in the design phase. Implementation of BIM resulted in improved coordination, increased design confidence, conflict detection, and simplified the construction phasing when BIM was employed in the design phase (Suermann, 2009). However, if the benefits of implementation of the BIM-model is that clear, why haven't the productivity of the construction increased more? I want to get more empirical data on the barriers of creating a rich BIM model form the design phase, and have formed the following research question;

What are the barriers of providing information to the BIM-model in the design phase?

2.5.2 Contractor organization and BIM

The objective of the general contractor is to coordinate the construction project to be completed within the timeframe and budget agreed with the developer (Sears et al., 2015). The BIM-model provides a collaborative platform for the stakeholders in the construction project and facilitates coordination and planning.

The contractor organizes each project with a unique assembled project-team (Cox & Ireland, 2002). Projects teams are seen suited for managing complexity with cross-functional business expertise (Hobday, 2000). According to Carrillo et al. (2004), the knowledge of the project team is highly essential for the construction project because the project-teams are based on-site where the physical construction,", and have limited contact with the in-house department. The importance of the project team reflects Gann and Salter (2000), which stress that the project team generates the value and profits for the contractor company. However, the knowledge of the project-team comes from past projects (Newell et al., 2006).

Eilif Hjelseth (2015) highlights that there was a lack of competence for handling the BIM-software, from his case study. Lack of competence for handling the BIM-software can be caused by the entrenched traditions of approaching the projects. It can also be caused because the contractors will not add any short term cost for project improvements, such as ICT-tools (Newell et al., 2006). Ghaffarianhoseini et al. (2017) bring attention to the lack of skills and experience of the project team and states that successful BIM adoption requires training for the employees.

Based on the literature, it seems like the knowledge of the contractors internal assembled project team will determine how the project is coordinated. Therefore, I want to understand if the project-team can impact the use of BIM-model. I have formed the following sub-research question;

In what way can the assembled project team impact the use of the BIM-model for procurement in a construction project?

2.5.3 Construction relationships and BIM

The main objective for the general contractor is to finish the construction project within the time and quality agreed with the developer. In order to accomplish this, the contractor needs to select the right suppliers, provide supervision, job coordination, and project billing (Sears et al., 2015). To what extent a general contractor chose to subcontract work depends on the project complexity. The suppliers bring essential competence for the contractor in construction projects (Frödell & Josephson, 2008). The construction industry is highly specialized, and a construction project consists of 80-90% of subcontractors (Hartmann & Caerteling, 2010; Ireland, 1996) and the contractor purchase materials for 70-80% of their turnover (Axelsson et al., 2005). Therefore, it is crucial for the contractor to secure a good collaboration with the suppliers and subcontractors.

The construction industry has tackled the partnerships through contractual relationships and fragmented involvement of subcontractors (Dainty et al., 2001; Fulford & Standing, 2014). Scholars suggest a supply chain focus will improve the collaboration in construction projects between the actors. The literature emphasizes the importance of information sharing in order to achieve integrated collaboration with a supply chain focus (Fugate et al., 2006). However, there has been an unwillingness from the contractor to exchange information openly (Saad et al., 2002).

By applying Fulford and Standing (2014) matrix (Appendix 1), the contractor should classify and determine their relationship with each actor, and then, the contractor should apply IT-tools to manage the information flow with these relationships. The BIM-model work as an information hub and a study by Lin et al. (2013) show that information sharing with IFC-files are accurate and provides rich data for the BIM-model. However, if the contractor uses the BIM-model for information sharing, it is essential that suppliers have access to relevant BIM-software, and, that the suppliers have the knowledge to handle the software.

The contractor must secure that the actors who add data to the BIM-model are aligned in how to provide the information. Gröger et al. (2008) suggest a standardized method for defining parameters and properties in the BIM-model. If the different IFC-files in the BIM-model is not aligned, the information will not provide value for collaboration (Eilif Hjelseth, 2015; Irizarry et al., 2013).

Selection of suppliers is often based on competitive bidding, where suppliers are selected based on the lowest price (Wegelius-Lehtonen, 2001). Irizarry et al. (2013) studies show that by applying the information from the BIM-model, it is possible to source suppliers based on more strategic factors. However, their approach required much information in the BIM-model from the design phase, and the suppliers had to provide the information to be able to get the output data (Irizarry et al., 2013).

The contractor can use the BIM-model to source suppliers on more strategic aspects. Furthermore, the contractor can use the BIM-model as an information hub for collaboration. However, this seems to be depended on the information the suppliers provide and if the subcontractors can handle the software. Therefore, I want to understand if the suppliers and subcontractors can impact the use of the BIM-model for procurement and I have formed the following sub-research question;

In what way can the suppliers and subcontractors impact the use of the BIM-model for procurement in a construction project?

2.6 Research framework

There is an agreement from the literature that the BIM-model can impact the procurement process in a construction project. However, the BIM-model needs to have a certain amount of information and LOD if it can impact the procurement more accurately. I have developed a research framework (figure 2), which I will use for my empirical analysis. The figure is developed based on the theoretical understanding of the reviewed literature. The research framework shows the process of implementing BIM-model. Further, the model shows the main contributors. In the model, there is a "layer" of barriers, which I will address in this thesis. By using the sub-research questions as a guideline for my empirical analysis, I will address the research framework. I hope to find empirical data on what are the barriers of providing the BIM-model with information. Furthermore, I hope to find empirical data on how the BIM-model can impact the procurement process in a construction project for a contractor.

The research framework; The process of implementing the BIM-model for procurement.

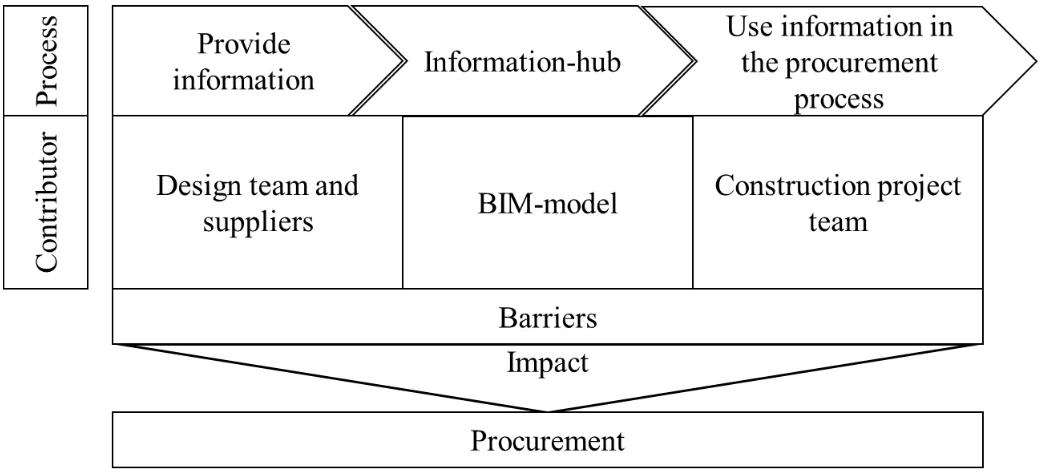


Figure 2. Research model based on theory, the process of implementing BIM

CHAPTER 3 – RESEARCH METHODOLOGY

To get an understanding of how the contractor procures in a construction project, there has been an observation of the construction practice, interview of employees, and interaction with the construction firm and its suppliers. A two months internship in the construction company Backe has provided insightful data collection on how BIM can impact the procurement process. The chapter provides a description of the research methodology chosen. First, the research strategy is presented, followed by the research design. Then the empirical setting is explained, followed by the data collection methods. Lastly, the analytical process is elaborated before the quality of the research is addressed.

3.1 Research Strategy

This research paper investigates how BIM-model can impact the procurement process of a construction project through a qualitative research strategy. A qualitative research strategy emphasizes words, and, can explain phenomena which are not possible to quantify (Bryman & Bell, 2015). Qualitative methods have been criticized for being too subjective, difficult to replicate, and problematic to generalize (Bryman & Bell, 2015). The objective of the research is to understand how BIM impact the procurement process for a construction project. The aim of the study makes a qualitative approach appropriate by understanding the non-quantifiable factors impacting the procurement process. A qualitative approach increases understanding through local perception (Bartunek & Seo, 2002). Furthermore, qualitative research is characterized as a more open-ended research strategy, linking key concepts in literature with the research (Bryman & Bell, 2015). A qualitative research method will contribute to an understanding of the dynamics associated with BIM and how it can impact the procurement process.

A part of the research strategy is how the scholar conducts his reasoning, where the objective of the reasoning is to justify the knowledge in the scientific field (Mantere & Ketokivi, 2013). In addition to deductive and inductive research strategies, it is also possible to have an abductive approach (Peirce, 1878). An abductive approach is a mixture of inductive and deductive but incorporates what inductive and deductive ignore, which is the meaning, interpretation, motives, and intention from everyday life (Blaikie, 2007). An abductive approach needs to acknowledge new findings through the research, as possible explanations and alternatives for the phenomena the researcher are exploring (Mantere & Ketokivi, 2013). Abductive reasoning could be viewed as one of the most important reasoning tools we use for both daily life and in scientific inquiry (Hanson, 1965; Harman, 1965; Lipton, 2003). Abductive reasoning could lead to scientific discoveries through the development of new hypotheses (Niiniluoto, 1999).

Dubois and Gadde (2002b) suggest a systematic combining to case studies because it can yield much, just like an abduction approach. However, systematic combining is closer to an inductive approach in the way that systematic combining does not discover new variables or relationship, but test existing theory through a non-linear model (Dubois & Gadde, 2002b). A systematic combining process consists of going back-and-forward between theory, the framework, the empirical world, and the case study, and is useful for the development of new theories (Dubois & Gadde, 2002b). Since I want to understand the relationship and variables affecting BIM and its relationship with the procurement process, I will use abductive reasoning. I will base my reasoning on the model (Appendix 4) developed by Dubois and Gadde (2002b). However, I will use the model to understand relations to BIM through abduction, and not to create new theory through systematic combining.

There are different strategies for analyzing qualitative data. Strategies of analysis provide a framework to guide the analysis of data and Bryman and Bell (2015) point at the grounded theory and analytic induction as two main strategies. Grounded theory has an iterative approach, which means that there is a repetitive interplay between collection and analyzing of data. Since the development of grounded theory by Glaser and Strauss, there has been a separation of the term and scholars argue that this separation could be necessary (Charmaz, 2014). However, I will base my data analysis on the interpretation of grounded theory by Bryman and Bell (2015).

One of the tools in grounded theory is coding, which generates the bone of the analysis (Charmaz, 2014). Coding enables me to define what is happening through an initial phase where I code the data found and later sort and organize the data. Data is broken down, examined, compared, and contrasted (Ellram, 1996). The coding will provide me with concepts and categories of data, and the more frequent the concept occurs, the more valuable it could be.

3.2 Research Design

In order to answer the research question, it is essential to give a plausible and reliable answer which the reader could understand. To provide a plausible and reliable answer, the research design must provide a framework for the collection and analysis of data. When considering the research design, constraints like time, budget, and competence are important factors because it influences the researcher capabilities (Ghauri & Grønhaug, 2005). When choosing a research design, Ghauri and Grønhaug (2005) argue that it is essential first to understand the problem structure. To understand how the BIM-model can impact the procurement process of a construction project is an unstructured and complex problem; therefore, an exploratory research method has been used (Ghauri & Grønhaug, 2005).

A suitable design to perform exploratory research would be a case study (Bryman & Bell, 2015), because it is field-based and let me observe the challenges and processes that occur in a construction company. A case study provides a detailed explanation of the practice, is suitable for theory building, and provides more understanding of the data gathered (Ellram, 1996). A case study will link real-life practice with theory. Backe will be the unit of analysis and will provide the research with unique data from the practice. Case studies are valuable when investigating contextual, dynamic, and emerging issues (Dubois & Salmi, 2016). When examining trends in the supply chain field, case studies could provide a valuable contribution to theory, because it offers strong exemplars as well as testing theories (Dubois & Araujo, 2007).

Researchers have expressed critique about the case study design because it is situation specific and not appropriate for generalization (Dubois & Gadde, 2002b). Statistical generalization depends on a significant number of samples, which a case study cannot provide when looking at a single company. According to Yin (1994), a single-case study should be chosen only if the company are extreme exemplars, unusually revelatory, or because the company provides the researcher with unusual research access. This is because single-case studies explore a significant phenomenon under rare or extreme circumstances (Eisenhardt & Graebner, 2007). A single-case study is chosen because of three reasons. First, the unit of analysis will provide unusual access to research data. Second, the unit of analysis could be viewed as a typical contractor firm. The company is in the range of the tenth biggest contracting firms in Norway, but not the biggest. Therefore, the findings will have value for other construction firms. Third, the unit of analysis uses BIM actively in their procurement process today.

When combining the complexity in the construction industry (Dubois & Gadde, 2002a) with numerous of software solutions related to the use of BIM and the interdependence between them, the result from a case study might not be applicable for every company. However, a qualitative case study has been identified as offering the most interesting research opportunities (Bartunek, Rynes, & Ireland, 2006; Suddaby, 2006), which is needed when investigating the complexity of construction. Case studies are rich in empirical data and are likely to produce theory, which is accurate, interesting, and testable (Eisenhardt & Graebner, 2007). The challenge with a single-case study is to present evident qualitative data to address the research question and to give a clear understanding of the case (Eisenhardt & Graebner, 2007). In order to do this, quotations from key informants and other evidence need to be intertwined with the theory to show the close connection between empirical evidence and theory (Eisenhardt & Graebner, 2007). The case study aims to understand how Backe, as a contractor, plan and execute the procurement process for a construction project. The empirical data will provide the research with valuable information from real-life practice and help answer the research question.

3.3 Data Collection

Collection of data is vital for the research project because it brings reliability and validity to the research. A case study strategy does not have a specific method of data collection (Yin, 1994), but a qualitative method requires qualitative evidence.

Precious data can be accommodated through a case study, such as interviews, archival data, surveys, ethnographies and observations (Bryman & Bell, 2015; Eisenhardt & Graebner, 2007; Yin, 1994). For this research, the sources of primary data collection have been interviews and observations and meetings (Appendix 6, and 8). In addition to this, there was access to all internal documents, and employees were available for clarification questions. By cross-examine the data collected, the validity of the data has been secured through a triangulation strategy (Bryman & Bell, 2015). Secondary data is defined as data collected by someone else for other purposes (Appannaiah, Reddy, & Ramanath, 2009). The secondary data in the paper is represented by academic articles, books, and organizational documents received from project participants and intranet (Appendix 7).

There has been a purposive sampling method for the research. Purposive sampling is a non-random sampling method where the goal is to sample based on strategic reasons, so, that those sampled are relevant to the research question (Bryman & Bell, 2015; Teddlie & Yu, 2007). There are different purposive sampling approaches and techniques, where sequential sampling is one type of technique. Teddlie and Yu (2007) describe sequential sampling as an evolving approach where the selection of units can change based on relevance to the research questions, as data are being collected. After each interview and meeting, I discussed the findings with my supervisor in Backe and planed next meeting or interview based on what I found. The purposive sequential sampling method led me to discover new materials and ask relevant questions for each new interview and meeting.

Bryman and Bell (2015) discuss the number of samples needed in order to achieve theoretical saturation. The scholars argue that it is impossible to know precisely the number of samples in a qualitative study. Onwuegbuzie and Collins (2007)state that the sample size in qualitative research should not be too small to achieve data saturation, theoretical saturation, or informal redundancy. Bryman and Bell (2015) emphasize that rather than say an exact number of samples, the research should justify the sampling method, why it was used, and why the sample size achieved is appropriate.

"If saturation is the criterion for sample size, specification minima or maxima for sample sizes is pointless. Essentially, the criterion for sample size it whatever it takes to achieve saturation."
(Bryman & Bell, 2015, p. 437)

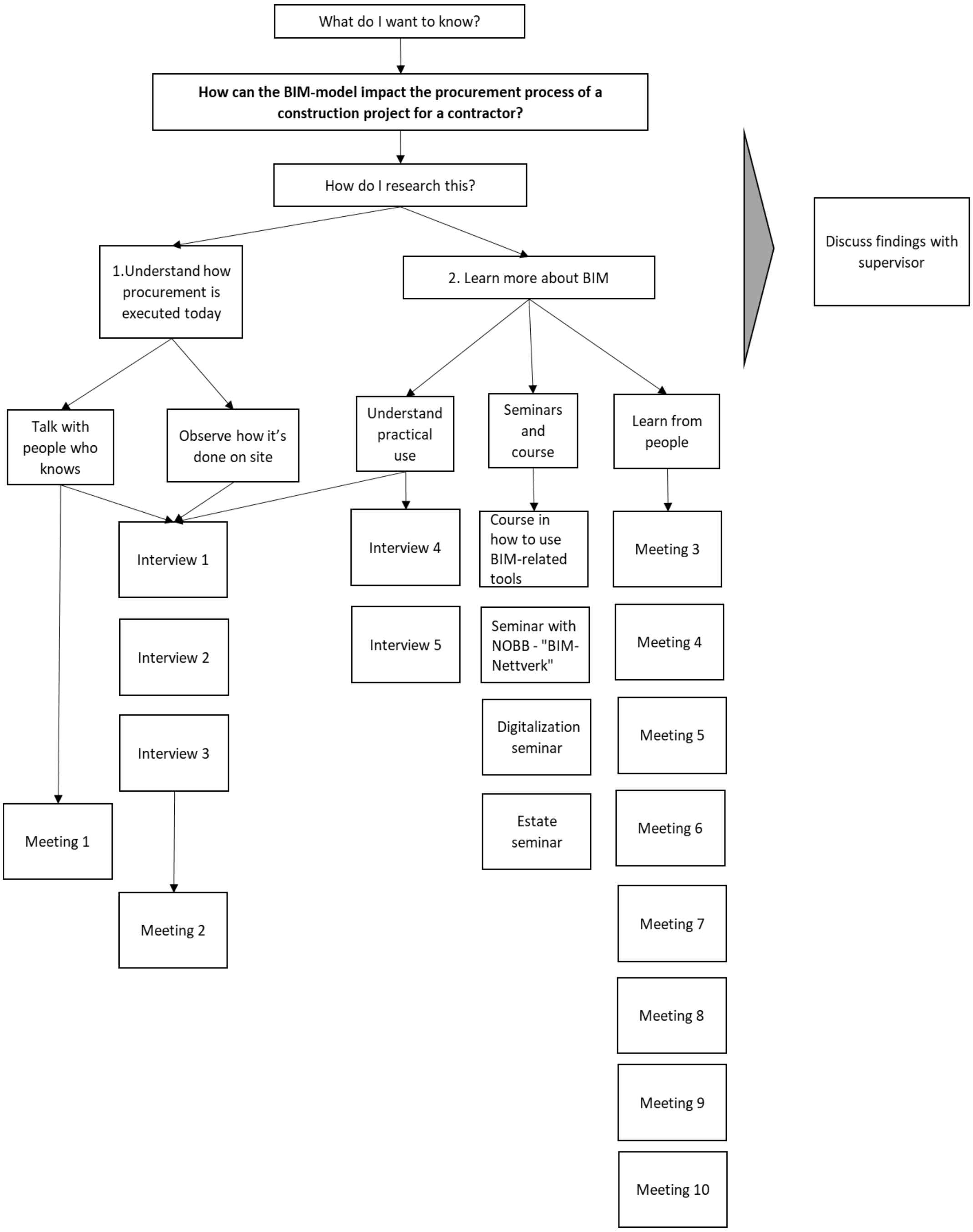


Figure 3. Overview of the data collection process

3.3.1 Primary Data

3.3.1.1Interviews

An interview is an excellent opportunity for collecting empirical data. It is essential to develop the right questions to be able to get valuable answers and to select highly knowledgeable informants with diverse perspectives on the addressed problem (Eisenhardt & Graebner, 2007). Within qualitative studies, Bryman and Bell (2015) suggest unstructured or semi-structured forms of individual interviewing. Semi-structured interviews consist of an interview guide, which is a list of questions and topics to be covered. Questions may not follow the given outline, and the researcher has the possibility of asking additional questions in order to get insight into relevant and vital information (Bryman & Bell, 2015). The semi-structured interviews gave the research a flexible collection of relevant information because it let me ask follow-up questions. The outcome of the interviews has been a collection of practical information about the procurement process in the construction project from the employees of Backe and the practical use of BIM.

A total of five interviews were conducted with project-members from three different projects, one supplier and one architect (Appendix 6). The interview guide (Appendix 5) was developed in a collaboration between a key leader and me from Backe. All interviews where done face to face and the answers were transcribed during the interviews. After all the interviews with the project members, the interviewer and I had a tour out at the construction site, and I got all the relevant documents for the project planning and the procurement process. The interview with the supplier was conducted with a key leader in the management of the supplier and found a place at the supplier headquarter. The supplier had a contract with Backe for the last four years. The interview with the architect was conducted at their own office, and Backe owned the architect company. All the interviewers were told the objective of the thesis and were asked to answer as honest as possible.

In terms of the number of interviews samples, five interviews are not high. However, after the third interview with the project leader, there was no new data found. The consensus between the project managers was strong. Because the consensus between the managers was strong, I did not pursue more interviews.

Besides, I discussed all the data with my supervisor in Backe, and the supervisor agreed upon the decision. A meeting with another supplier backed the interview with the supplier. Also, the findings from the supplier build upon what the project leaders said. Therefore, I did not believe there was information redundancy by not interviewing more suppliers. However, the interview with the architect could have been backed up by more interviews. Because I used CAD-programs and got practice on how to BIM-files, I found the interview with the architect to be accurate. The interview with the architect was used partially to understand the design phase. From observations and meetings, I got much data to confirm the data collected from the architect. Therefore, I did not ask other architects for a formal interview, just discussed the findings I had. The empirical data match much of the literature found, and I argue that the data saturation was achieved.

3.3.1.2 Observation

Observation is when a researcher has immersed in a group and observers the behavior by listening to what is said and done (Bryman & Bell, 2015). Case studies can contribute to valuable evidence through direct observations (Yin, 1994). Dubois and Gadde (2002b) state that theory cannot be understood without empirical observation and that empirical observation could result in the identification of unknown and related issues that might not be explored through interviews or other means of data collection. ‘Passive’ data is what the researcher is searching for, while ‘active’ data is found through discoveries. Observations could lead to a great discovery of ‘active’ data (Dubois & Gadde, 2002b).

Ethnography is a type of observation method, where the researcher immerses in a field or a group for an extended period, in order to observe the behavior and ask questions for the collection of data (Bryman & Bell, 2015). Ethnography requires an investment of time in the field and will provide detailed observation evidence (Yin, 1994). In order to conduct a good observation, I have been working for Backe. Eight hours a day, Monday to Friday for two months is the time I got to do my observation and work with my research question. Working for a company and conducting practical observations is not new. Roy (1959) spend two months as a machine operator, isolated with a small group of workers and spending long days together.

When conducting observation with ethnography, it is possible to have a covert role. A covert role is when the researcher does not tell the employees that he is a researcher (Bryman & Bell, 2015). The benefits of a convert role are that there is less chance of change in behavior when talking with the employees. The disadvantages are that the research will not have the same possibility of taking notes of the observation, which is an important task when conduction ethnography (Bryman & Bell, 2015). To secure that information was not misunderstood or lost, all data was written down. Therefore, a covert role was not chosen. During the observations, all relevant information was collected and wrote down. I always validated the findings with employees of Backe and asked follow-up questions if needed. The observations allowed me to get a deep understanding of the construction industry and how the BIM-model could impact the procurement process.

3.3.1.3 Meetings and attendances

Because I was an employee of Backe, I was able to attend and schedule meetings with key stakeholders in the construction industry (Appendix 7). Attending meetings was part of my triangulation strategy. Attending meetings allowed me to get information which could be difficult to collect through other methods, such as interviews. The reasons for this are because many of the meetings were about plans and problems which are not discussed outside the meetings. I was able to attend meetings for employees of Back, which people outside of the firm would not be able to attend.

When I scheduled and invited to meetings, I was able to have more open discussions and get the information I would not get if I only followed an interview-guide. I always wrote down key information from all the meetings I attended and asked questions if I did not understand the information given. The purpose of the meetings was not only to get information about the procurement process for a construction project, but the purpose of the meetings was also to get an overview of the bigger picture, understand new technology trends for BIM and understand the dynamics of construction firms. The meetings gave me inspiration and broader understandings. Further, I collected information about new software tools for BIM, and I collected information on how suppliers worked towards digital solutions and their views on how to use BIM in the procurement process. I also attended seminars and courses. The seminars gave me insight into other digitalization projects and provided empirical data on BIM.

3.3.2 Secondary Data

3.3.2.1 Literature review

The literature represents a variety of literature from the construction industry and the supply chain field. The construction industry is global; therefore, the literature review represents research from many different countries. Literature can be collected through a structured search strategy or a chaining technique(Bryman & Bell, 2015). There has not been a structured search strategy; rather this paper has collected literature based on a chaining technique, where it is used more significant topic keywords as ‘BIM,’ ‘Construction,’ ‘Procurement,’ and tracked references to find relevant articles.

3.3.2.2 Organizational documents

To supplement the primary data collection, it was collected organization documents. The documents were collected from the intranet and the project leader. The type of document, where it was retrieved from, and the ground of getting the document can be found in Appendix 7.

3.3.3 Research Steps

Abductive reasoning has been used. The abduction reasoning provides the research with a back-and-forward method for collection and interpretation of data, where the research steps in non-linear. The research steps are illustrated in figure 4. Figure 4. is built upon the systematic combining approach (Appendix 4). The idea of this approach is to confront theory with the empirical world. This has made the data collection able to have continuous development throughout the research process of the thesis.

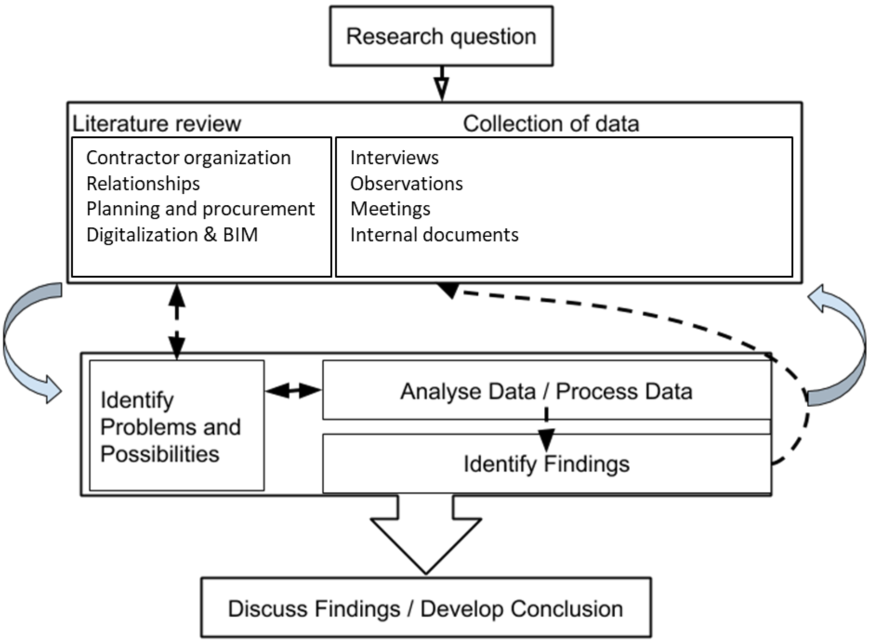


Figure 4. Visualization of the research steps.

3.4 Data Analysis

3.4.1 Analytical Process

As outlined in the research strategy, the research has followed the logic of systematic combining, as shown in figure 4. The study started through one of the coursed at BI, where I wrote an outline for a research paper. I found literature on BIM and the construction industry and started to read more about the topic. As I got more knowledge of the construction industry, the interest of BIM grew. There was so much data on how BIM could impact the construction industry. Yet, many studies were indicating low productivity and small margins in the industry. At the end of the course, I had written an outline of the research method and formed a research question. However, with all the literature I had read about BIM and construction, I could still not understand why the construction process was not more digital. Therefore, I contacted Backe and asked for an internship. Through the internship, I would get the empirical data to answer my research question.

When I started in Backe, I discussed what I learned from the literature with one of the managers in the company. Together, we formed the research question and looked at different construction projects which would be appropriate as subcase studies. We discussed the literature and developed the interview guide. During the next two months, observations, meetings, and interviews were conducted.

After the data were collected, I started mapping my empirical data and linked it with the theory from the outline of the research. Before I collected data, I made a strategy of how to research (Figure 3). I divided the data collection into "Understand how procurement is executed today" and "Learn more about BIM." By dividing the data, it was easier to structure my findings. All the interviews were transcribed, and I had a notebook where I wrote down information from every meeting and attendance I had. For the interviews, I also created categories which formed the questions in the interview guide. By creating groups for the questions, I could separate the theoretical findings.

During this process, there was much theoretical data missing compared to the empirical observations. I found the first literature review to miss key concepts form my empirical data. The theoretical data could not provide enough information to the groups I had created. So, I started reviewing more literature. Due to practical experience from the construction industry, much of the literature began to make sense. I found information from the literature I had overseen earlier.

After more literature had been reviewed, I found much of the key concepts covered. From there, I started the discussion and conclusion of the paper.

3.5 Quality of the Research

3.5.1 Quality Criteria

The scientific quality is vital in order to conduct good research and to demonstrate the credibility of the findings. Miles (1979) gives credit to qualitative data for its rich and 'real' data but points to the concern about validity and reliability. One way of securing quality in case studies could be through the aspects; construct validity, internal validity, external validity, internal reliability, and external reliability

(Ellram, 1996; LeCompte & Goetz, 1982; Yin, 1994). Another way of providing quality in a qualitative study is to overcome the trustworthiness through the four criteria; credibility, transferability, dependability, and confirmability (Lincoln & Guba, 1985). In addition to trustworthiness, qualitative research should have authenticity. Despite the efforts of meeting Miles (1979) concerns, there is still no consensus in how to analyze and present qualitative data in order to convince the readers of the real value and quality (Hannah & Lautsch, 2011). I will now discuss the four aspects from LeCompte and Goetz (1982) in combination with the four criteria's from Lincoln and Guba (1985) of trustworthiness in order to reflect upon the quality and trustworthiness of my research. I will not discuss the authenticity aspects of the research, and this is because it concerns the more political aspect of the research (Bryman & Bell, 2015), which should not be a problem.

External *reliability* refers to the replication of the study. There are arguments against how easy it is to replicate case studies (Bryman & Bell, 2015). Given the fact that I have chosen a case study with an ethnographic twist, you could say that it will be hard to replicate my study. However, I believe a qualitative study should bring new ideas to the research field and enlighten the research question with information from the chosen case study. Doing business research, and looking into new digital solutions, there will be a dynamic focus of technology, in the industry you are searching, and thereby no case studies of new technology are easy to replicate. In other words, it is impossible to freeze a social setting. According to LeCompte and Goetz (1982), a strategy to secure external reliability is to adopt a similar social role as the original researcher. Therefore, I have described my role in Backe to secure the external reliability of the research. Also, through my interview-guide much of the data collected will be possible to find, if you conduct a replicate study.

Further, internal *reliability* is the agreement within the group. Since I am writing alone, I have not a fellow researcher to discuss my findings with. However, I discussed much of the observed data with my supervisor in Backe. I interpret the observed data, and we agree upon my interpretation in order to make sure the observed data would bring value.

Lincoln and Guba (1985) parallel understanding of reliability is *dependability*, where they suggest scholars keep a record of all the phases of the research process. According to Bryman and Bell (2015), this has not become a pervasive approach for validation because it is very demanding to keep all the records.

Internal *validity* is parallel to *credibility*, where Lincoln and Guba (1985) recommend triangulation as a mean for increasing the credibility, and thereby the trustworthiness. By conducting interviews, attending meetings, and observations, I have triangulated the data validity through multiple data sources. Triangulating the data from different sources is called data source triangulation (Denzin, 2017). In addition to talking with my supervisor in Backe, I talked with people from the industry at seminars to discuss my understanding of the data I collected. This made me gain insight from multiple sources and increase my understanding of the research question. Also, internal validity reflects the match between observed data and theoretical data. Through the mapping of literature and empirical data, I found a great match. The discussion reflects the match between the sources.

External validity refers to the possibility of generalization of the finding (LeCompte & Goetz, 1982). External validity is parallel to *transferability*, where Lincoln and Guba (1985) point out that whether the findings hold in some other context, or even in the same, is an empirical issue.

Case studies are criticized for not easily being generalized and replicated (Bryman & Bell, 2015; Dubois & Gadde, 2002b). By addressing these issues, I tried to understand the contractor industry through my literature review and use the literature as a guideline for how the BIM-model can impact the procurement in a construction project, rather than focusing on internal problems for Backe. By using the literature as a guideline, some of my observed data should be applicable for generalization and should be of interest for other contractors in the industry. Furthermore, the construction industry is highly complex, and the findings from this study will not capture all related factor for how the BIM-model can impact the procurement.

CHAPTER 4 – EMPIRICAL FINDINGS AND ANALYSIS

In this chapter, I will present the empirical findings and analyze the data. Based on the literature review, I have developed sub-research questions, which will be used as a guideline for the analysis. With the sub-research questions, developed through a discussion of the literature, my empirical findings will address the literature. This method of addressing the literature will create a good fundament for discussion in the next chapter. Each of the sub-research questions will address the practice of the contractor and explain the construction process and the use of BIM.

What are the barriers of providing information to the BIM-model in the design phase?

The first phase of a construction project is the outline of the project. The outline of the project is part of what the contractor uses for the competitive bidding of the construction project. In the competitive bidding, the contractor will outline how the project will look like, the estimated time to build the project and the estimated total cost of the construction project. The contractor chooses an architect firm to work with and create the outline of the project. From the interviews, there was a joint agreement that the outline of the project was the basis for the calculation of cost and time, in terms of the competitive bid. The outline of the project was created as a BIM-model and presented in a Power-Point.

What I found was that the modules in the BIM-model lacked detailed information. Since the outline is created for the competitive bidding, the BIM-model is not fully developed. It is essential to notice that during the discussion, there is not a difference between modules and objects in the BIM-model. By looking at the outline of project one, there was found details of the type of materials which was going to be used in the construction project. However, the materials from the outline are just suggestions and not necessarily used in the construction project. The interview with the architect confirmed that there was a lack of details in the outline of the project.

Further, the architect emphasized that more detailed information requires more time. It means that the BIM-model can be detailed with much information if enough time is put into it. Also, the architect emphasizes that the level of information is dependent on the LOD required from the contractor. There is a higher requirement for the LOD in the BIM-model when the contractor wins the project and moves to the design phase.

In the design phase, the architect will collaborate with the consulting engineers and develop a BIM-model with more details. The consulting engineers have different responsibilities, and each will create parts of the BIM-model, IFC-files, based on their field of competence. There are different consulting engineers for electrics, fire, acoustics, and much more. From this point, I will refer to the consulting engineers and architect as the design team.

Backe has created a document called “BIM-manual,” which is a guideline for how the consultants should create their parts of the BIM-model. During the design phase, the design team and the internal project team will meet for coordination. The contractor has a BIM-coordinator which is responsible for the development and accuracy of the BIM. However, the project leader has the primary responsibility of the BIM. The project leader uses BMC for clash control and will give feedback to the design team if there are mistakes. The design phase is not complete before the construction and procurement phase start. My findings suggest there are two reasons why the design team is not finished with the design of the BIM-model before the construction and procurement of the project starts.

Time is one reason why the BIM-model is not finished before procurement starts. The reasons why time is a barrier for creating a finished BIM-model is separated into multiple reasons. The first constraint is the time limit for the design phase. The time it took from the contractor had signed the agreement with the developer, and until the construction and procurement phase started, was under three months. Within those three months, the BIM-model had to be developed by the design team, and the contractor had to plan the construction project and procurement. From project three, there was found approximately 15.000 clashes from the first BMC of the outline of the project. Even if the design phase is not complete, the procurement and construction phase has to start the date agreed between the developer and the contractor.

"The first date of construction is agreed with the developer. If construction does not start that day, there will be cost penalties. Therefore, it is better to start construction early, even if the design of the construction project is not complete."
Project leader

The architect emphasizes that there takes much time to create a fully detailed BIM-model, which is the second reasons why there is not enough time to create a BIM-model with a high LOD. There are different ways of creating modules for the BIM-model. The design team can create each module and insert all the information they like, where the object name and parameters are manually inserted. Alternatively, the modules can be added through add-ons, such as "NTI Tools" in CAD programs such as Revit. From "NTI Tools," the models are standardized with information, and the design team can add or change values as they like. A third option is to download modules from "BIMobject.com" and use the pre-made modules in the model. These modules are created from suppliers and contain detailed information about specific products. The practice today is to re-use modules from previous projects, to save time. However, collaboration with these modules can be problematic because they are not standardized across the design team.

"Previously made modules are saved in the architect company's library and is not shared with other architects."
Architect

The pre-designed modules have the benefit of containing much information. However, much of the data needs to be changed because contractors make their guideline for how to structure and name the modules in the BIM-model. For instance, Backe has their BIM-manual, which describes how the consulting engineers and architects must structure the data. If the information provided in the

BIM-model is not aligned with their BIM-manual, functions like BMC will not provide valuable output.

There are indications that the value of a BIM-model with high LOD is overseen. When I investigated the BIM-manual for one of the projects, significant parts of the content were removed. The BIM-manual contains information about how to name objects, the responsibility of the design team, coordination, and how to collaborate with IFC-files. However, parts of the document where removed because the project team did not see the value of the document. The architect expressed the same concern.

"A BIM-model with a high degree of information is beneficial and will improve the estimated calculation of material quantity and time for the construction project. However, it is hard to make the contractor see this value. Therefore, BIM-model is not 100% accurate because much of the information is not used anyways."
Architect

The indication that the value of the BIM-model is overseen is contrary to what the project leaders expressed. Also, the managers in the main office had a strong belief that BIM should contain a high degree of LOD. There was even hired a new BIM-specialist during my time with Backe. As I followed up on the discussion, there was expressed concern about how much information the BIM should contain. My understanding was that the value of a BIM-model with high LOD was not the problem; the problem was with who should bear the cost of all the work it took to create the BIM.

"If it were more precise information about each object and not just modules, then there would have been more precise quantity calculations from the model, which would have provided more trust to the BIM."
Project leader

I attended a seminar for a digitalization project where they illustrated how the BIM-model, with another software, could be used to calculate the total cost of the project automatically. The software could also estimate a project plan, and the software could send product orders directly to suppliers. The supplier would receive the product order, where the project plan set the delivery date of the product. It was also possible to see the price change of the project if materials were changed. The digital procurement was possible because the BIM-model had a high LOD. The contractor understood the value of BIM and let the design team created the whole BIM-model with pre-made modules from the suppliers. The construction used as a pilot was approximately 200 sqm. standardized house the contractor sold. Therefore, each construction project had already been designed, and the design phase was not needed for the second, third, or fourth house sold. The case showed that by providing a BIM-model with much information in the design phase, the BIM-model could impact the procurement process with more accurate information and more efficiency. The result is a project with fewer errors and control over procurement cost.

In what way can the assembled project team impact the use of the BIM-model for procurement in a construction project?

The process of a construction project is standardized if you look from a manager's perspective with a turnkey contract. The developer will create an outline of the project. Then, contractors will estimate the cost and time based on the outline and bid on the contract. When the contractor wins the contractor, there will be a design and planning phase. Then there is a procurement and construction phase before the construction is completed and delivered to the developer. However, within these phases, observation of the construction processes indicates that there is no standardizes method. When I attended a project scheduling meeting, I observed the interaction between the internal project team and the external subcontractors. There were discussions about whether the plumber or the electrician should start their work first in the construction phase, and the process manager from Back had to challenge the process between the subcontractors. The project leader determines the project schedule and must coordinate the subcontractors based on experience and knowledge. The empirical data focus on the internal project team and how they can impact the use of BIM for procurement.

The project leader has the primary responsibility for procurement. When the project leader plans procurement for a construction project, it is based on the project schedule with a combination of their own experience and BIM-model. The project schedule is created in a Gantt-chart and contains the workflow of each subcontractor. There is a general agreement that the BIM-model is not good enough for the actual planning of the procurement.

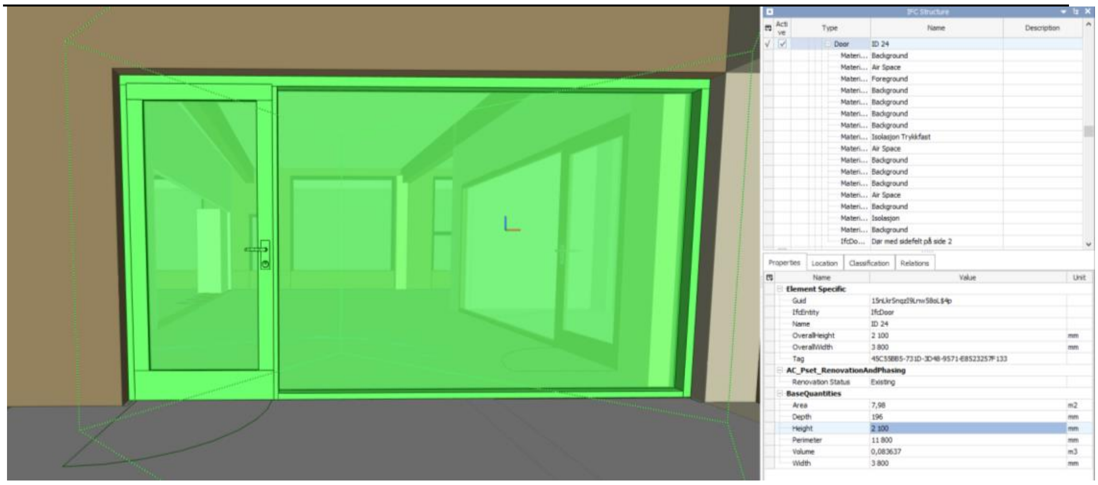
"The project schedule is based on my own experience and not the BIM-model. The procurement plan is based on the project schedule."
Project leader from project 1

"The first project schedule was thrown. The scheduling of the project went to hell because of the BIM-model contained so many mistakes."
Project leader from project 2

When the project schedule is set, the planning of materials starts. All the construction projects used BMC for calculation of material quantity and specifications. When using BMC for material quantity and specifications, many mistakes occur, and there is a need for checking the actual object to validate the information.

Component	Type	Bounding Box Height	Bounding Box Length	Count	Color
Door	Dør	6,36	3,76	3	
Door	Dør med sidefelt på side 2	16,8	9,6	8	
Door	Dør metall tofløyet	8,4	8,8	4	
Door	Dør tofløyet	4,24	3,44	2	
Door	Dør tofløyet med 2 sidefelt	6,3	7,2	3	
Door	Leddport	2,09	2,63	1	

Overview of information provided with a BMC of the BIM-model. (See document list)



A door module in the BIM-model, where the green object is what has been defined as a door. (Source: From BIM-model of project X)

What we can see from these findings is that since the door is not separated from the glass, the whole module will count as one door. Therefore, the BIM-model needs to be manually checked when the project leader wants to get the specifications on each type of door. The door example is just one of many and results in a lack of trust by the project members.

«The quantity of materials will be extracted from the BIM-model and BMC, but often it is simpler to look at the 2D drawings and measure the sizes with a ruler to get more precise information about the quantity and size of bigger objects. This is done because you want to reduce mistakes of wrong information because the BIM-model is not developed correctly."
Construction site manager

After the project leader has created the project schedule, the project leader will send an E-mail or call different suppliers and ask for their delivery time. Depending on the delivery time, the project leader will mark the dates when materials need to be ordered.

"We usually contact the supplier and ask for the delivery time for our most critical materials. Based on experience, we know the delivery time for the rest of the materials. Then we look at the project schedule to note when the materials are needed."
Project leader

Project changes will impact the project schedule, and thereby impact the procurement of materials. In a construction project, the project developer can make changes after the design phase. The project developer can decide to build an extra floor or change parts of the project. Therefore, it is important that the contractor sets the limit of the changes. The contractor can use a document called "Developer decision plan" where the contractor and developer determine the last date for changes in the construction project. Looking through the project files for project x, y, and z, neither of the projects had determined a project decision plan with the developer. Since the design phase is not finished, and there are changes in the project plan after the construction has started, the project leader tries to order materials as late as possible.

"There are sudden changes in the construction project; then the BIM-model model needs to be updated. The issue is that the project developer does not understand that these changes have a high cost."
Project leader

"BIM-model is rarely finished before the construction starts. There are changes in the BIM-model during the construction phase."
Architect

Findings from observation on the construction site indicate that the contractor lacks control of procurement. During my observation from one of the construction sites, one of the workers explained that much of the materials, which supposedly was delivered from the supplier, were not possible to find at the construction site. The workers stated they had searched the construction site for 20 minutes and could not find the materials. The project leader called the supplier an asked if the materials were delivered. The supplier could not tell if the materials were delivered or not but promised to bring new materials within two hours. The project leader uses an Excel-file to keep track of material requirements, which is what they refer to as their procurement plan. The Excel-file contains information about the material and the date the material is expected to be used in the construction. Because there are delays and changes in the construction project, the project schedule is rarely accurate.

"The project schedule is out of date immediately after we have created it."
Project leader

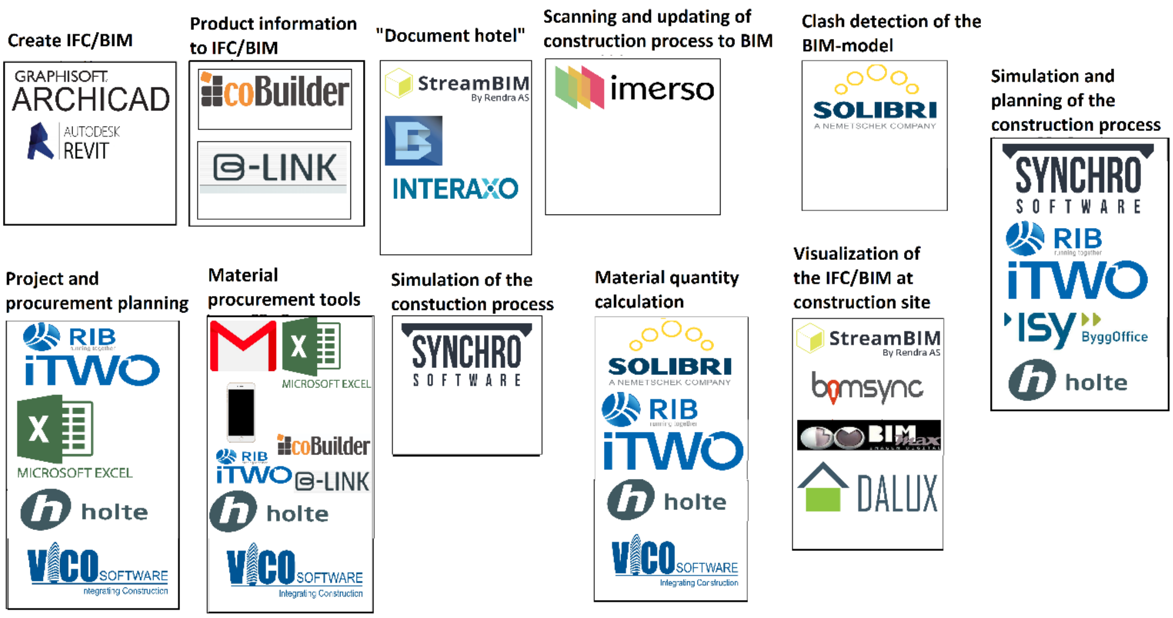
There is a collective agreement between the contractors that material orders need to be postponed to the actual construction; it is only the most critical materials that are procured early. When the contractor orders the critical materials, they ask the supplier for a delivery flex of a couple of days. The materials remaining, the "noncritical," is planned on a daily or weekly basis. One example was pre-made baths, which has an extended delivery time. The pre-made baths were ordered 12 weeks in advance while plasterboards were ordered one day in advance of construction.

"When the construction has started, then the materials get ordered. The project leader will go through the construction site at the end of the day and take notes of how far the construction phase is, and what materials that are needed. This will be written down in the procurement plan. The workers will also notify if they need any materials."
Project leader

There are software tools which can impact the procurement process with the BIM-model. The different projects used many of the same software tools for improving the construction project. However, there were only a few different software-tools used, and the performance of these tools was not well addressed. One of the younger construction site managers used software called Synchro. Synchro enabled the manager to visually create a timeframe of the project based on the BIM-model. By utilizing the timeframe, the manager created a project schedule and planned the procurement based on this project schedule. Whenever there was a change in the BIM-model, the manager had to redo the whole process. The manager pointed out that the process was time-demanding and difficult. I discussed the potential of implementing Synchro for all the construction projects in Backe, but employees of Back emphasized the software were difficult to use. The manager explained that the lack of practical experience was the reason for using technological tools.

"Using Synchro demands quite a lot of time. The reasons I use it is because I do not have as much experience as the other project leaders. I have to compensate with technological tools to secure a good project schedule."
Construction site manager

Through my observations and meetings, I saw many software-tools which promised to impact the procurement and construction process. However, these tools do not provide any value if the project team is not using them. What I discovered was that there a different reason for why the project-team does not include more software-tools or utilizing the tools they already have in their construction projects.



Overview of some of the software-tools that are available in the market. The software-tools are grouped by the functions they provide.

Based on my findings, there is an indication that the project managers lacked competence in using software tools. Because there is a lack of competence, many of the project leaders try to avoid additional tools and prefer to work in the way that they always have done it.

"I have noticed that others do not use the BIM-model because they lack the competence in how they use it."
Construction site manager

"You got a program like dRofus, which is excellent for planning and information sharing across the stakeholders in the construction project. However, it is not commonly used today."
Architect

Backe decided to implement a software-tool called "Stream BIM" across the whole organization. Stream BIM provides a visualization of the BIM-model on a computer or an iPad. The software-tool had considerable success in projects and improved the visualization of the construction process. It took under one year from the first pilot project until every construction project in Backe utilized the software-tool. Backe continuously had courses for its employees on how to manage the software-tool Stream BIM.

I attended one of the training courses for Stream-BIM with employees from subsidiary x. During the course, I notice that the older employees had difficulties in utilizing the software-tool. During the course, I had to repeat what the teacher showed us and help some of the employees with tasks in class. One of the reasons why the employees do not have the competence of using new software-tools could be lack of experience with technological tools. When there was talk about changing one of the finance-tools, an older employee said he was glad he soon was going with pension because it took him ten years to learn the one, he was using today.

Further, my findings suggest that another reason why the employees do not have the competence of using the software-tool to utilize the BIM-model and impact the procurement process is that there is no time for learning.

When a new project start, the project leaders emphasize that there is no time to learn new software tools. The construction site manager had to use leisure in order to learn Synchro. Because the manager, through own initiative, wanted to learn

Synchro, Backe paid for the course. However, talking with other employees, many of them said that there was too much to do in the project, and there was not time to learn new software-tool in between projects. When I asked what the most significant challenge with the BIM-model is, one of the interviewees replied;

"I think it is difficult to learn how to use the BIM-model. Today, I use to much time on BIM, and especially since the model does not work for this project."
Project manager

My findings indicate that trust in the BIM-model is another barrier for not utilizing the BIM-model for procurement in the construction project. Throughout my observations and interviews, the employees agreed that the BIM-model was not good enough for procurement. Bad experience has caused a lack of trust in the model.

"It takes too much time to get the quantity of materials from BIM, and there is low trust in the result. Often, you will find "Wall type 1", but there is no information about what type of plasterboard, type of concrete or anything. You can get the calculations, but the calculations would not be right."
Project leader

In what way can the suppliers and subcontractors impact the use of the BIM-model for procurement in a construction project?

The contractor has limited contact with suppliers and subcontractors before the procurement and construction phase starts. Some of the subcontractors are included in the project planning. The primary collaboration is when the construction phase has started. There is a weekly meeting to discuss the progress in the construction phase, and the project leader is responsible for the subcontractors to make sure they follow the project schedule. Subcontractors are separated into their field of competence and must fulfill their contract with the general contractor. Subcontractors procure their materials. Therefore, the project leader will not have anything to do with what the subcontractor purchase. Because it is a distance relationship between the actors, I have not found useful data on how the subcontractor can impact the use of the BIM-model for procurement. I have found more empirical data on the relationship between the supplier and the contractor. In all the projects observed, the general contractor, Backe, was responsible for the production of carpentry and concrete.

Backe negotiates agreements with suppliers. The suppliers with an agreement will be put in a supplier list. The list includes suppliers for equipment, clothes, marketing materials and much more. The subsidiaries are required to use some of the suppliers but not all. The objective of the supplier list is to provide good agreements for all the subsidiaries. The supplier list only contains a discount factor, and there is no agreement on how to communicate, delivery method, or other information. The project team members expressed the discontent of the arrangements. Some project members said they instead choose other suppliers and determine their agreements with suppliers.

There are mainly three methods of ordering materials in today's practice; Phone, E-mail, or from the supplier's website. The most common way of ordering is by phone and E-mail. Contractors emphasize that the suppliers do not have a proper ordering method.

"The supplier offers a website platform for the ordering of materials. We usually do not use it because it is time demanding and difficult to use, and most of the functions do not work."
Project leader

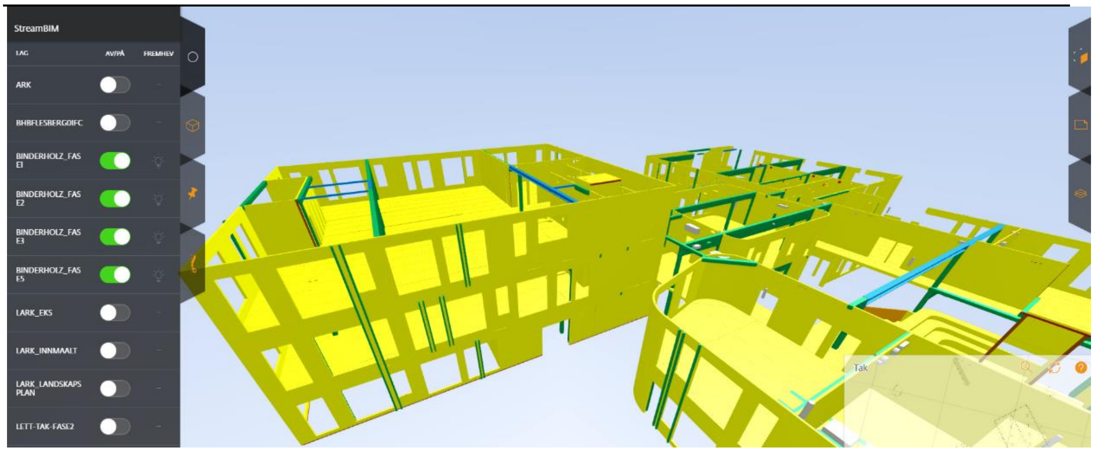
After the materials are ordered, the suppliers usually send an order confirmation by E-mail. When materials are delivered to the construction site, there is poor communication. If some of the ordered materials are missing, the project leader will not be noticed until the delivery of materials. Then the contractor needs to call the supplier and ask why materials are not delivered. Because the communication between the supplier and the contractor is mainly based on E-mail or a phone call, it is hard for the contractor to keep track of the ordered materials.

"We will get the confirmation of ordered materials on E-mail, but we do not receive any information if the supplier cannot deliver materials before the actual material is delivery on the construction site. This result in delays for the construction."
Project leader

When materials arrive at the construction site, the contractor lack control of handling the materials. There are different persons set to take care of the material delivery, but it is not well organized. The project leader, construction site manager, the BAS, or just workers handle the material delivery at a construction site. The supplier delivers materials at different times of the day and does not communicate at what time the delivery will happen. There is no IT-system between the two parties.

"When the supplier delivers materials, we look at the material; then we look at the order confirmation to make sure it is right. We have to trust the supplier."
Project leader

One of the project leaders contacted a supplier of wooden construction early in the design phase and asked the supplier to deliver the finish material in an IFC-file. The collaboration with the supplier resulted in a 3D drawing of the finished material. With this solution, the supplier could give a precise quantity and price of the finished product and helped the project manager with calculating the project schedule for the construction and plan the delivery of materials. The supplier improved the procurement for the construction project because they got involved early in the design phase.



This is the BIM-model, based on the IFC-file from the supplier, which is the result of collaboration with the supplier early in the design phase. (Source: From BIM-model of project X)

From this example, the supplier was included early in the design phase. The supplier had information about their products, and the BIM-model was used as an information-hub. By providing all relevant information about the wooden construction in the IFC-file, the supplier and contractor could collaborate with the BIM-model.

Involvement of suppliers is not typical in today's practice. From one of my meetings with another supplier, the supplier emphasizes that control of their materials required good IT-systems and information. The supplier is known for being best in class with logistics and material delivery to construction sites. At the meeting with the supplier, we looked at how they controlled material orders before a truck delivered the material to the construction site. With RFID on each material, the products were scanned, and each delivery was checked two times before it was sent. This process has created control of material delivery. When materials are delivered at the construction site, the workers can use an app, to make sure the material delivery is right. In addition to this, the trucks which delivered the materials has GPS, and the project leader would have control of material delivery. Correct delivery and good collaboration are a result of information about their products and good IT-system. With a mobile application, the customers had control of when the material was going to be delivered, the list of materials and the customer decide at what place materials were going to be delivered. However, Backe does not use this supplier because they have an agreement with another supplier. The supplier Backe uses is the one interviewed for this research.

Findings indicate the project leaders do use the BIM-model for logistics planning. The focus is the date the materials should be delivered. There were only one of the project leaders who planned for a logistics schedule at the construction-site, but the plan was thrown when the project schedule was changed.

My data suggest that the reasons why procurement of materials is not efficient in the construction projects are because the supplier does not have good IT-systems and control over their supply.

"We are working towards a standardized method of delivery, but we do not have the software for this today. Improving our IT-systems is part of our strategy, there are too many mistakes today, and we have no control of delivery."
Supplier

It was a general agreement between both suppliers that they wished they were included earlier in the construction process. If they were included in the design phase, they could provide information valuable for procurement.

"We have employed a BIM-technician because we think we will be included in the design phase of the construction. If we do, we can provide valuable information for the procurement of materials."
Supplier

CHAPTER 5 – DISCUSSION

Based on the empirical analysis and the literature review, I will discuss my findings. The discussion is based on the sub-research questions developed from the literature review. After each sub-research question, there will be a conclusion. The conclusion from the sub-research question will help answer the research question on *how can the BIM-model impact the procurement process of a construction project for a contractor?*

What are the barriers of providing information to the BIM-model in the design phase?

There is a collective agreement between scholars that the BIM-model requires a certain level of information in order to provide value for the construction project (Ghaffarianhoseini et al., 2017; Eilif Hjelseth, 2015; Irizarry et al., 2013). Empirical observations indicate that the level of information in the BIM-model is not that high yet. The architect explains that there are three methods for creating the BIM-model, and it is possible to create a BIM with high LOD. The level of information is determined by the time the design team put into the model, and the requirements form the contractor. If the BIM-model does not contain enough information, it is not possible to use it for electronic procurement (Grilo & Jardim-Goncalves, 2011).

One of the barriers of providing information to the BIM-model in the design phase is the time limit. Sears et al. (2015) explain the design, construction, and procurement phases as overlapping phases, which is in accordance with what the practice shows. One project had three months for design and planning of the construction project. The overlapping phases result in a short amount of time for the design team to design the BIM. The empirical data shows that BIM-model is the basis for project planning. Williamson et al. (2004) stress the fact that it takes time to create a virtual supply chain. By looking at the information flow (Appendix 3) developed by Irizarry et al. (2013), the information used in the supply chain come from the development/design of the BIM-model.

If three months is enough time to create a BIM-model with rich data depends on the project complexity. From the literature, I have not found the optimal time for creating a BIM-model. By looking at the process of creating a BIM-model from the empirical data, we see that the project starts with the outline. The contractor uses the outline of the project as the fundament for design, but the low information level requires the design team to add much information to the model in the design phase.

According to Zavadskas et al. (2010), information technology can provide better decision making because technology can evaluate multiple attributes. The scholars emphasize the benefit of IT is only possible when it is appropriately implemented. Practice today shows that the BIM-model is created with pre-made modules from the architect. The reason for creating the BIM-model with pre-made modules is because it is time-saving for the design team. Also, the information in the pre-made modules is not standardized across the design team. Therefore, the contractor needs to separate how modules are defined based on the IFC-files. Irizarry et al. (2013) and Lin et al. (2013) stress the fact that how information is structured needs to be agreed upon in the design team. The fact that the design team creates the BIM with pre-made modules indicates that there is not enough time to create a project-specific BIM. In order to get a project-specific BIM, the contractor has created the BIM-manual.

The BIM-manual is a document used for collaboration between the design team members. Lin et al. (2013) show that the modules in the BIM-model need rich data and description to provide value for collaboration. The objective of the BIM-manual is to secure a BIM-model with valuable information for the project. According to Gröger et al. (2008), when modules and products are defined with properties and parameters, there need to be a universal language and standardized method for the project team, to provide value. Still, some projects removed parts of the BIM-manual before the document was sent to the design team. The BIM-manual does not say anything about the level of details is required in the BIM. Information like geometry, light analysis, geographic information, fire rating, U-values and spatial relationships provides comprehensive information of the construction project and can be stored in the BIM-model (Ghaffarianhoseini et al., 2017). The

BIM-manual does not specify the type of information the BIM requires before the procurement process starts.

The architects understanding is that the BIM-model is only partially used. The architect does not think the contractor see the value of a BIM-model with high LOD. From the literature, there is definite proof that the BIM-model needs to contain much information in order to provide value. By looking at the matrix (Appendix 2) developed by Eilif Hjelseth (2015), more information in the model provides more opportunities. Therefore, the contractor must require a higher LOD in the BIM before the procurement and construction phase starts. The projects leader thinks a model with more information will provide more precise calculations for the construction project and increase the trust of the model.

The empirical example of the standardized houses shows the opportunity of a construction project with a BIM-model made as-build. Because the BIM-model has a high LOD, the contractor can use the information from the model for planning and procurement. The result is accurate cost and quantity calculations, and additional software-tool can order materials directly from the supplier. However, it is essential to look at the project size of the standardized house. This research has collected empirical data form projects valued in the hundred million class. The literature emphasizes that construction projects are complex. Moreover, the complexity and size of the project require much time to create a BIM-model with a high LOD. The complexity of the project should be the reasons for creating a more detailed BIM in the design phase because a more detailed BIM will provide more accurate cost and quantity calculations.

To conclude, there are two barriers to providing information to the BIM-model in the design phase. The first barrier is the length of time for creating a BIM model. The second barrier is the value for the contractor; if the contractor sees the value, there must be a requirement to create the BIM-model, with a high LOD, before the procurement phase starts.

In what way can the assembled project team impact the use of the BIM-model for procurement in a construction project?

The project team is based on-site of the construction. According to Carrillo et al. (2004), the knowledge of the project team is highly essential for the construction project. Empirical data also indicates that the knowledge of the project team is essential. Moreover, the knowledge of the project leader is highly important for the construction project. The empirical data provides an understanding of the project leader's role.

From the definition of a contractor, the objective is to organize and supply materials for a construction company (Dictionary, 2019). Further, Hobday (2000) emphasize the coordination and integration role of the contractor. Literature suggests boundary management, as one way for the construction industry to get more control when managing the project activities (Fellows & Liu, 2012; Ruuska et al., 2011). Boundary management refers to managing the necessary activities between multiple parties in order to carry out the task at hand (Fellows & Liu, 2012). The project schedule includes the activities between the parties. In that way, it can be argued that the project schedule is one type of boundary management.

The project schedule is done with Gantt chart and describes each work-flow. However, the project managers are not satisfied with the planning tool and draw attention to the project schedule as being outdated the second is it created. Scholar has also drawn attention to the Gantt chart as being too static and unmanageable in more complex projects (Milosevic & Martinelli, 2016; Taxén & Lilliesköld, 2008). It is safe to suggest that the project schedule should be conducted through other methods, where the BIM and related software could be a better solution. BIM is a type of boundary spanning technology, and scholars suggest boundary spanning technology could lead to better collaboration between the stakeholders in a construction project (Cox & Ireland, 2002; Shen et al., 2008).

The practice today is to create a project schedule as the basis for the procurement plan. The project leader creates the project schedule based on experience in a Gantt chart, where the BIM-model contributes as a helping tool. Observations show that the BIM-model is used for planning the quantity of materials in the construction project. The project leaders use BMC for estimating the quantity of materials. However, the project leaders draw attention to the low quality of the BIM. Data provided shows that the modules in the BIM lack detailed information. The lack of details results in data outputs from the BMC, which must be checked manually in the BIM-model. The empirical data suggest that poor BIM-modeling from the design phase results in a BIM-model with low value, which is in line with the study of Eilif Hjelseth (2015). Irizarry et al. (2013) state that the model requires a great deal of data input before the model can provide a valuable contribution to procurement.

Even if the model had a low LOD, one of the construction managers took advantage of the BIM with alternative software tools. There are different software tools to support the use of BIM for procurement. However, the project team used mainly the software tools provided by the main office. Scholars draw attention to the low affinity for digital technology among the labor pool in the construction industry (Friedrich et al., 2011; Leviäkangas et al., 2017).

Ghaffarianhoseini et al. (2017) bring attention to the lack of skills and experience of the project team. Eilif Hjelseth (2015) found lack of competence for handling the BIM-software in his case study. Lack of competence for using the BIM is found from the empirical observations. There are indications that the lack of competence is the reason why project leaders do not include alternative software tools in the procurement process. Lack of competence could also be the reasons why the managers could not use the BIM-model more accurately for planning and procurement. The lack of experience and competence in handling BIM could be because the accumulation of the project team's knowledge comes from past projects. Newell et al. (2006) emphasize that processes in construction do not change because of the knowledge of the project team is gathered from previous projects. Using BIM in construction projects in a new phenomenon for Backe, and it is only during the last year that BIM-software were implemented in all projects.

Sudden changes in the construction project create challenges for the use of the BIM-model. From my literature review, I have not found data on how to meet the challenges of sudden changes from the developer. The empirical data shows that the developer decision plan was not used in any of the construction projects. Sudden changes from the developer create changes both for the BIM-model and the procurement phase. A study by Sambasivan and Soon (2007) showed that slow decision making from the developer caused delays for the construction project. However, improper planning and site-management are the leading causes of project delays.

Ghaffarianhoseini et al. (2017) state that successful BIM adoption requires training for employees. When Backe implemented Stream-BIM, it only took one year before every project started using the software tool. There are indications that the lack of interest and no time for learning are two reasons why the project team does not have the competence of using software-tool or trying new software-tools. Another factor for the lack of competence could be due to the investment in technology. The project managers used the software-tool provided. According to the literature, the spend on information technology accounts for less than 1 percent of revenues in the construction industry (Agarwal et al., 2016; Leviäkangas et al., 2017). A study by Leviäkangas (2016) showed that there is a correlation between investment in digitalization and labor productivity. The construction manager learned to use Synchro because the company paid for courses. Based on this, there should be more investments in technology in order to increase interest in additional software-tools.

Project leaders have much influence on the construction project, and the project managers expressed their lack of trust in the BIM. The bad experience with the BIM-model result in low trust in the model. Low trust in the model results in a distance use of the model. The lack of trust is a barrier for the project team for not utilizing the BIM-model.

To conclude, the assembled project team can impact the use of the BIM-model for procurement with software-tools. The project leaders set the boundaries for the project team and set the requirements for the BIM-model. But first, the project team needs competence and skills for utilizing the software-tools. Also, there needs to be more trust in the BIM-model before the project team can use the BIM-model to impact the procurement process. The contractor should invest in technology and training for the employees.

In what way can the suppliers and subcontractors impact the use of the BIM-model for procurement in a construction project?

The general contractor is responsible for the procurement process, which includes sourcing, purchasing, contracting, and on-site material management (Habibi et al., 2018; Nethery, 1989). In all three projects, the general contractor could only impact the procurement process of carpentry and concrete. The other subcontractors managed their suppliers and materials, as shown in Figure 1. The discussion will be based on how the contractor can manage these suppliers.

To improve the performance of the construction industry, scholars suggest integrating business processes and follow the principles of supply chain management (Briscoe & Dainty, 2005; Ekeskär & Rudberg, 2016; Vrijhoef & Koskela, 2000). The processes are not integrated today, and scholars draw attention to the contractors fragmented approaches towards relationships (Bresnen & Marshall, 2000; Chan et al., 2003; Egan, 1998). The scholars argue that there is fragmentation because the design is separate from production and involvement of suppliers often has been postponed and not included before later in the project stages. The empirical observation shows the fragmented approach towards suppliers. The involvement of suppliers is limited to information about material delivery through E-mails. Project leaders do not include suppliers in the design or planning phase of the construction. A supply chain is a collection of partners working towards a common goal, connected through financial, informational, and service flows (Fugate et al., 2006). Fulford and Standing (2014) recommend better project management through better information flow and investment in IT as implications for better collaboration in the construction supply chain.

One of the projects included a supplier early in the design phase, resulting in an IFC-file for the materials. The collaboration with the supplier resulted in accurate pricing of materials and material delivery planned to the project schedule. The involvement of the suppliers improved the planning of the project. The project leader included the supplier because the materials were crucial to the project. According to Fulford and Standing (2014), the contractor should distinguish suppliers based on relationships- requirements and capabilities when determining how invested the company should be with the suppliers. The relationship with the supplier of the wooden construction could be characterized as a strategic relationship, through the classification form figure 7. (Appendix 1).

A case study by Frödell and Josephson (2008) showed that one of the greatest strength identified in the relationship between the contractor and one its biggest suppliers were the competence for the products the supplier brought to the projects. The expertise of the supplier brought great value to the project. The IFC-file of the product gave the contractor a broader understanding of how to work with the wooden construction, and the BIM-model was used as an information hub.

Collaboration with suppliers through the BIM-model is not frequent in today's practice. Observations show that procurement through E-mail, and the phone is the most common method. One reason is that the supplier does not have the IT-system to provide better procurement. Procurement through E-mail and phone results in a lack of control and project delays. Findings from a case study by Osawaru et al. (2018) showed that 75% of construction sites encountered delays due to untimely deliveries. However, 80% of construction sites places the orders for materials between one and two weeks of the requirement day. The scholar highlight that late ordering of materials may result in delays and recommend a prompt ordering of materials from local suppliers when possible. The findings from the scholars are in line with the findings from the observations. Project leaders control their procurement with an Excel-file, and there is no IT-system for collaboration between the parties. By including the supplier earlier in the process, the supplier could help the contractor with the planning of materials and reduce the uncertainty of demand. By reducing the uncertainty of demand, the total cost of the relationship could be decreased (Frödell et al., 2013)

Scholars agree that companies can not only select suppliers based on cost, but has to select suppliers based on more strategic aspects (Chuan et al., 2016; Gadde et al., 2010). The list of suppliers with agreement did not show any strategic reasons, only a percentage for discounts. The project member expressed the discontent of the agreements and wanted to use other suppliers.

One of the suppliers I met could show IT-system for collaboration. The supplier used RFID to keep track of materials and had GPS on their cars for control of construction-site delivery. There was even a mobile application where it was possible to follow the car and see the delivery time. Implementation of IT-systems has been suggested for improving the efficiency of material planning and delivery on the construction site (Omar & Ballal, 2009). The information flow in the supply chain (Appendix 3), requires much information in order to provide value. The information provided by the supplier would provide much of the required information to create the information flow in the supply chain. However, Back did not use this supplier.

It is important for Backe to include their strategic suppliers early in the design phase because it results in project improvements. By including the supplier, the contractor will overcome the arm’s length and adversarial relationship with the contractor. The arm’s length and adversarial relationship between the contractor and the supplier is one of the reasons why the contractor cannot follow the principles of supplier chain management (Briscoe & Dainty, 2005). By integrating and including the supplier earlier in the design phase, the BIM-model will work as a collaborative platform and contribute to connecting the informational flow between the contractor and supplier. According to O'Brien et al. (2008) and Saad et al. (2002), supply chain management can improved processes like demand, design, material requirements planning, and product delivery. Information delivery will improve construction logistics, which will result in better productivity, avoiding delays, and reducing waste (Rebolj et al., 2008)

To conclude, the supplier could impact the use of BIM-model by providing accurate information about materials. However, first, the contractor needs to include the supplier earlier in the design phase and take advantage of the information the supplier provides. Also, the supplier needs to have the information and systems in order to collaborate through the BIM-model. The contractor cannot choose the supplier based on cost but must select a supplier with the necessary technology. If suppliers are included earlier, the BIM will work as a collaborative platform connecting the contractor and supplier. The collaborative platform will facilitate the parties working towards the principles of supply chain management.

Based on the three sub-research questions, there has been a discussion of the literature and the empirical findings. Each of the sub-questions has ended up with a conclusion. The conclusion from the sub-research questions has been put into the research framework and gives an overview of the barriers for implementing the BIM-model in the construction project.

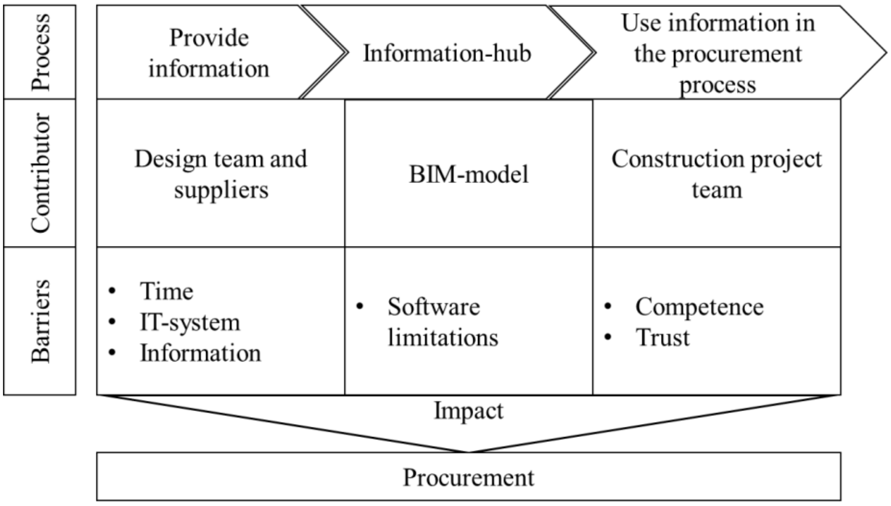


Figure 5. Research framework based on the discussion, the process of implementing BIM.

CHAPTER 6 – CONCLUSION

To conclude the research, a case study of the construction company Backe was performed. Interviews, observations, and meetings were conducted. Then the collected data and organizational documents were reviewed and analyzed. Previous research has identified opportunities with BIM. However, there has not been a clear explanation of the barriers when implementing BIM. The research found that construction projects at Backe have a BIM-model, but the BIM-model does not provide the expected value. Project managers would instead use their own experience in project planning and would not trust the BIM to provide valuable information. In today's practice, BIM is used for creating a visualization of the project, and the design team does not provide accurate information. Suppliers are not included in the process before the actual procurement starts. The project managers postpone material orders if possible, and there is no system for collaboration with the supplier. Suppliers cannot provide an exact time for material delivery, and materials are not strictly handled at the construction site, leading to lost productivity.

Literature and empirical data have been discussed regarding the barriers of implementing an accurate BIM. The research has identified areas for the contractor to improve in order to implement and utilize the BIM-model. The BIM-model can impact the procurement process by providing accurate information and work as a collaborative platform. By providing precise information, the project team will improve their quantity calculations and time estimations, resulting in more accurate project planning. By providing a collaborative platform, the supplier can contribute with valuable competence to the project. The project team will have more control over order material, and software tools can optimize material delivery. A collaborative platform will result in less material waste, increased productivity, and strengthen the relationship with the suppliers

Based on the research question of how the BIM-model can impact the procurement process, a research framework has been applied throughout the paper. The research framework was developed based on the interpretation of the literature review. The discussion of the empirical data and literature discovered the barriers of implementing a BIM with a higher level of details. The conclusions have provided an answer to the research question.

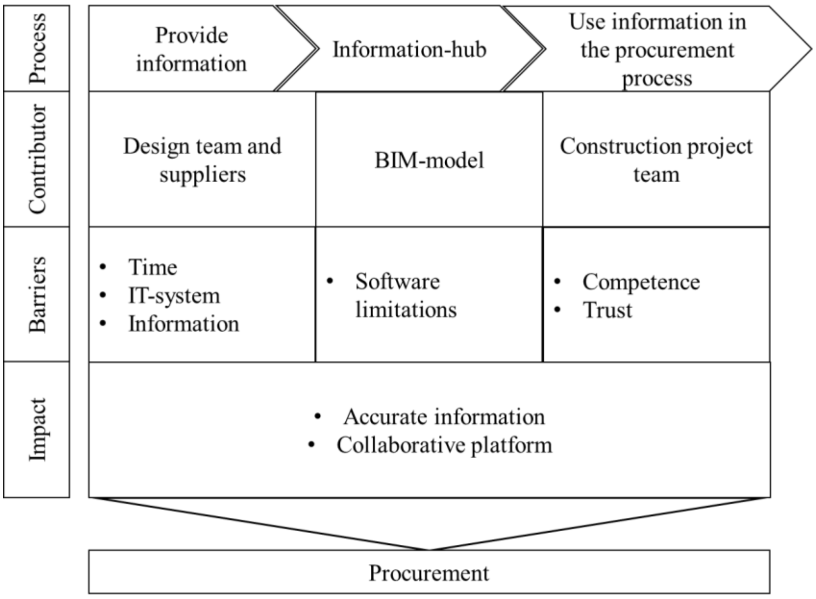


Figure 6. Research model based on the conclusion, the process of implementing BIM and the impact on the procurement process

6.1 Practical Implications

The discussion has provided a conclusion to each of the sub-research questions and will be used as the basis for answering the research question: *How can the BIM-model impact the procurement process of a construction project for a contractor?* The conclusion of the research question is based on the literature and findings from the empirical data. There will be a reference to the theory when it is cohesive with the findings of the paper when the research question is answered.

For the BIM-model to be able to impact the procurement process of a construction project for a contractor, I have identified some areas of improvement for the contractor:

- *Create a common agreement on the level of detail in the BIM-model before procurement starts.* The contractor should set a minimum requirement for the design team of how much information the BIM-should contain. The contractor should clarify the minimum LOD with the developer and postpone procurement and construction until the design of the project meets the required LOD. More accurate models will contribute to a higher trust in the model and fewer errors for the procurement process.

- *Include strategic suppliers in the design phase.* The contractor should take advantage of the supplier's knowledge and include suppliers in the design phase. In this way, the supplier can contribute to creating a more accurate BIM-model for procurement. When choosing strategic suppliers, the contractor needs to evaluate more than just the cost of the supplier and select suppliers that have technological solutions for collaboration in BIM.

- *Invest in additional software-tools.* The contractor should invest more in additional software-tools and training for the employees. Even if the short-term cost may be high, the project managers will benefit from software-tools. More experience and training will create more competence for project managers and lay the foundation for improved procurement and higher margins in future projects.

When the contractor has focused their attention on these areas of improvements, the BIM-model can impact the procurement process of a construction project for a contractor by:

- *providing accurate information.* By utilizing the BIM as an information-hub, the software tools provide accurate calculations of the material quantity and time estimations, resulting in improved project planning (Eilif Hjelseth, 2015; Zhang et al., 2016). Accurate information will improve conflict detection and improve the coordination of subcontractors (Eilif Hjelseth, 2015; Suermann, 2009). Furthermore, accurate information will reduce the uncertainty of demand, which leads to a reduction in cost (Frödell et al., 2013). Accurate information enables total cost calculation and better decision making by the project managers (Irizarry et al., 2013).

- *providing a collaborative platform.* The digital representation of the construction project enables collaboration in a multidisciplinary team through the transfer of digital data and specifications between different software applications (Ghaffarianhoseini et al., 2017). With software tools, the BIM can keep track of the supply chain status and provide information about the delivery of materials to the construction site (Irizarry et al., 2013). A collaborative platform will strength the supplier relationships and facilitate supply chain management, which will improve the quality of the project and impact the cost and time of the project (Fulford & Standing, 2014).

6.2 Theoretical implications

The findings from the paper contribute with three theoretical implications.

There is a collective agreement between scholars that the BIM-model requires a certain level of information in order to provide value for the construction project (Ghaffarianhoseini et al., 2017; Eilif Hjelseth, 2015; Irizarry et al., 2013). From practice, BIM-models was found providing some value to the project. The output of the BIM was not always accurate, and project members preferred not to use the BIM. Based on this, and the empirical findings, I have developed a theoretical implication:

> *If the design team invests more time on creating a BIM-model, the BIM-model will improve and provide more accurate information to the procurement process of a construction project.*

The theory states that integration with suppliers will increase the commitment and accountability from suppliers (Fulford & Standing, 2014). When suppliers provide information, it is possible to calculate the total cost of the relationship and select the most appropriate supplier (Tserng et al., 2006). Including suppliers early in the construction process enables information-flow in the supply chain (Irizarry et al., 2013). The theory is by the empirical findings of the paper, and a theoretical implication has been developed:

> *If strategic suppliers are included earlier in the project phase, the BIM-model will provide more accurate information to the procurement process of a construction project.*

The theory states that the knowledge of the project team is important for the construction project (Carrillo et al., 2004). BIM is an information technology (Leviäkangas et al., 2017), and information technology improves collaboration in the construction supply chain (Fulford & Standing, 2014). The empirical data supports the theory and contributes with the following implication:

> *If the project managers are provided with more competence and skills with software tools related to BIM, the BIM may be used as a collaborative platform for the procurement process of a construction project.*

6.3 Limitations and Recommendation for Further Research

The paper has identified several areas of potential improvement for the contractor. One of the limitations of this study has been to measure the level of details in the BIM-model. None of the studied projects could tell the exact LOD of their BIM. It is possible to provide the model with significant amounts of information, but not all information will necessarily provide value for the procurement process. Future research should study what the optimal level of details in a BIM-model before procurement starts.

Construction projects do not keep track of how many hours the design team spends on creating the BIM because the design team is compensated per project. Therefore, the study has been limited by providing the hours spent on design in the construction projects. Future research should study the optimal time of creating BIM-models, and to what extent the level of details exceeds the value it provides, for procurement.

The paper has investigated the procurement process concerning the supplier of carpentry materials. The research has not been able to gather information about other fields of suppliers, such as electrician and plumber. There has not been a collection of information about other suppliers because the contractor mainly collaborated with the carpentry supplier. Therefore, there should be further research if the practical implications of this study would bring value for all types of suppliers.

The age of the project leader could influence the skills of handling software tools. There are only two indications about the age impacting the handling of software in this study. These indications come from one of the interviews and experience from one of the meeting. Further research should investigate how a lack of practical experience from construction can be compensated with skills in handling software tools and if there is any correlation with age the handling of the software.

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Appendix

Appendix 1 – Classifying and determining relationships

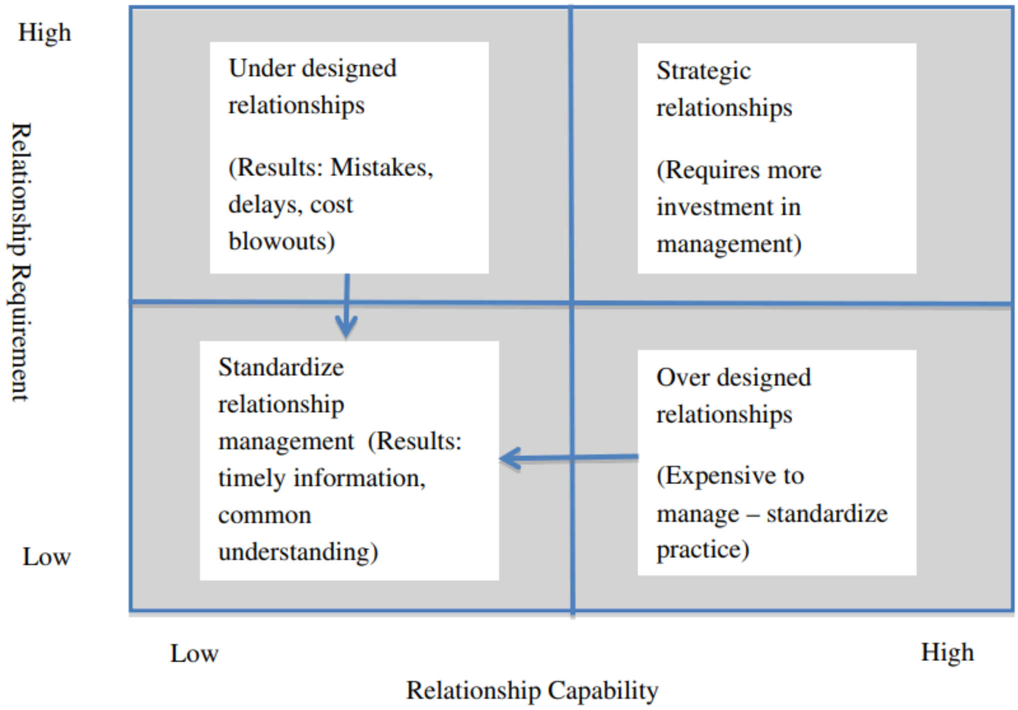

Figure 7. Classifying and managing relationships developed by Fulford and Standing (2014)

Appendix 2 – Classification of BMC levels for compliance and content checking

Content of information "I in the BIM"

Specific purpose checking Standard software Adding specified values to existing properties in BIM-objects. Advanced content checking. *Level 3*	**Integrated model checking** Adding values according to specifications in new properties in BIM-objects. Advanced content checking. *Level 4*	**Pervasive model checking** BIM of multiple integrated models Compliance checking with wide scope. Dedicated rule-sets Replace manual checking. *Level 5*
Adjusted model checking Standard software Adding values for existing properties in BIM-objects. *Level 2*	**Specific purpose checking** Compliance checking of specified scopes. Compliance checking of dedicated domains. *Level 3*	**Integrated model checking** Adding new properties and values according to specifications of new BIM-objects. *Level 4*
Clash detection checking Standard software Geometric checking of interference. Default values, no adding of values to properties. Support manual checking *Level 1*	**Adjusted model checking** Standard software Adding values according to specifications in existing properties in BIM-objects. *Level 2*	**Specific purpose checking** Guidance Standard software Adding new properties with values to relevant BIM-objects. *Level 3*

Complexity of digital rules

Figure 8. Classification of BMC levels for compliance and content checking by Eilif Hjelseth (2015)

Appendix 3 – Overview of information flow in the supply chain

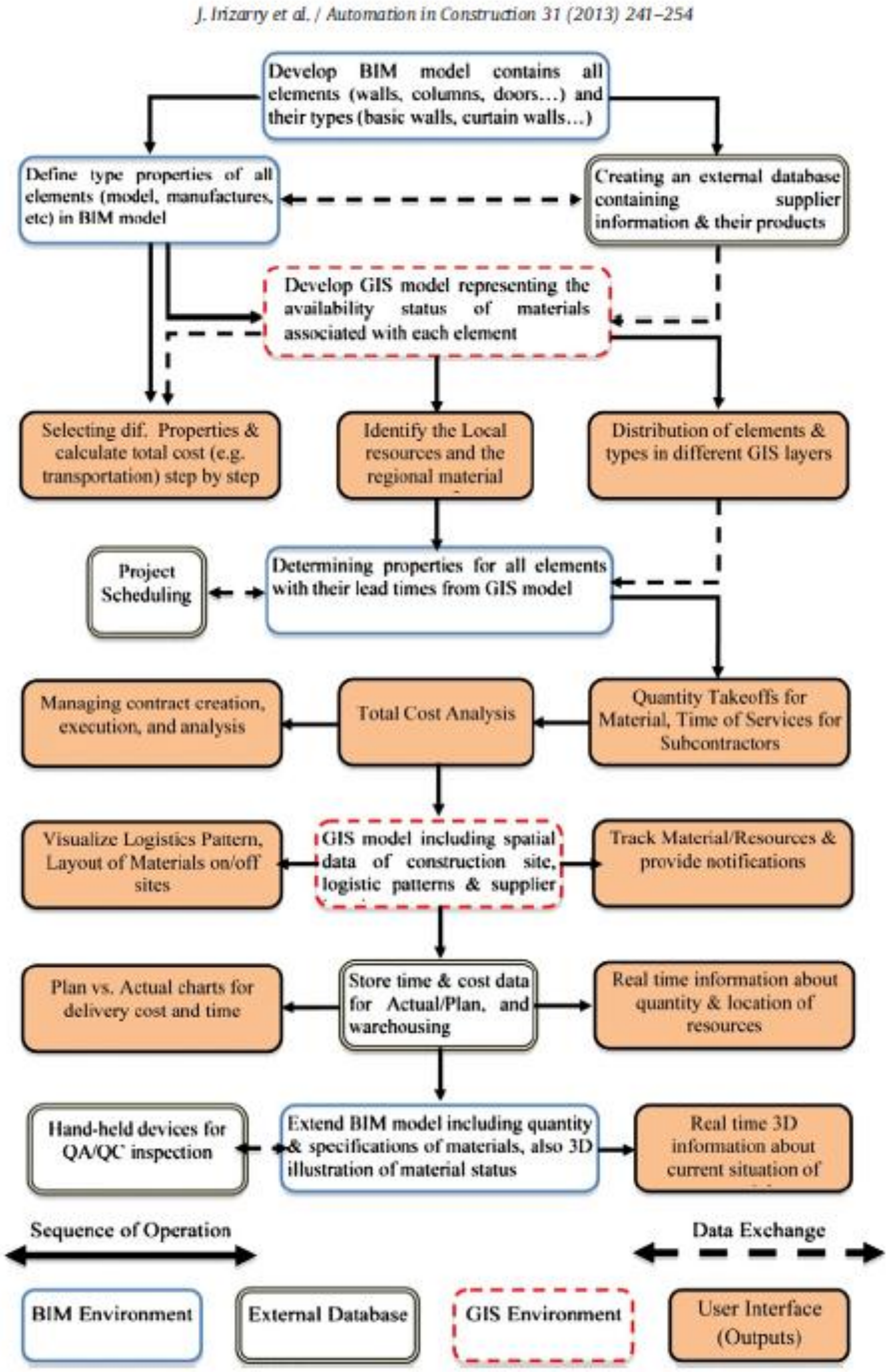

Figure 9. Information flow in the supply chain model by Irizarry et al. (2013)

Appendix 4 – Systematic Combining model

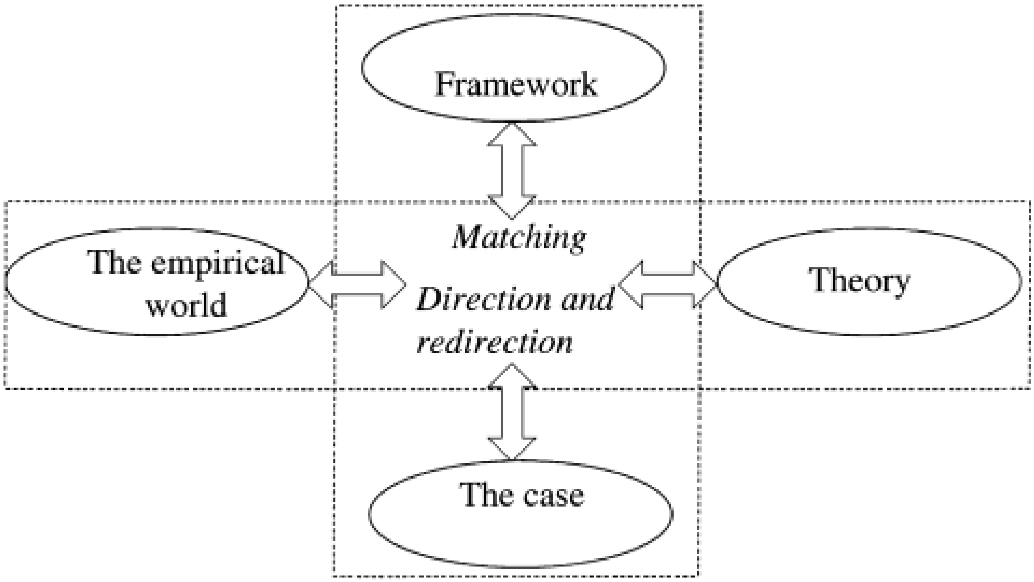

Figure 10. The systematic combining approach developed by Dubois and Gadde (2002b).

Appendix 5 – Interview Guide

Interview Guide – Internal Project Team

Forskningsspørsmål: Hvordan kan BIM-modellen påvirke anskaffelsesprosessen i et byggeprosjekt for en entreprenør?	
Innledning: Jeg skriver en masteroppgave hvor jeg ser på hvordan anskaffelse av materiale og håndtering av materiale på byggeplass kan påvirkes av en BIM-modell. Fokuset er på prosessen i dag, hvordan dere jobber i prosjektet, bruk av BIM i dag, og hvilke muligheter dere ser for dere videre. Målet med oppgaven er å kartlegge mulighetene man har med en BIM-modell og forstå hvordan modellen kan brukes til å forbedre dagens prosesser.	
Tema	Spørsmål
Planlegging	Hvordan planlegger dere innkjøp av varer til ett prosjekt i dag?
	Hvordan finner dere ut hvilke menger dere skal bestille?

	Hvordan finner dere ut når (i tid) dere trenger varene
	Hvordan planlegger dere logistikken på ett bygg prosjekt i dag?
Samarbeid	Hvordan samarbeider dere med leverandør av materiale?
	Hvordan samarbeider dere med arkitektene og rådgivende ingeniørene?
Produksjon	Hvor langt i forveien bestiller dere?
	Hvordan bestiller dere? (EDI, Web, Mail, Telefon)
	Hvordan holder dere orden på planlagte leveranser?
	Hvordan utfører dere godsmottak? (kontroll av mengder, kvalitet, skader, dokumentasjon, lagring av varer, interntransport, etc.)
	Hvordan dokumenteres godsmottak? (papir, skanning, signering.)
	Har dere noe system for å håndtere godsmottak?
BIM-bruk	Hvordan bruker dere BIM til innkjøp av varer i dag?
	Hvordan brukere dere BIM til planleggingen av logistikk i dag?
	Hva er de største utfordringene/manglene med BIM i din arbeidshverdag?
	Har du noen tanker om hvordan disse problemene kunne bli løst?

Interview Guide – Suppliers

Forskningsspørsmål: Hvordan kan BIM-modellen påvirke anskaffelsesprosessen i et byggeprosjekt for en entreprenør?	
Innledning: Jeg skriver en masteroppgave hvor jeg ser på hvordan anskaffelse av materiale og håndtering av materiale på byggeplass kan påvirkes av en BIM-modell. Fokuset er på prosessen i dag, hvordan dere jobber med prosjekter, bruk av BIM i dag, og hvilke muligheter dere ser for dere videre. Målet med oppgaven er å kartlegge mulighetene man har med en BIM-modell og forstå hvordan modellen kan brukes til å forbedre dagens prosesser.	
Tema	Spørsmål
Håndtering av informasjon	Hvordan bestiller næringen varer fra dere i dag? (Mail, tlf, nett)
Samarbeid	Hvordan samarbeider dere med entreprenøren?
Planlegging	Hvordan planlegges levering av varer til et byggeprosjekt?
Produksjon	Hvordan kontrollere dere at leveransen er riktig?
BIM-bruk	Hvordan bruker dere BIM-modellen til levering av varer?
	Hvordan standardiserer/koder dere produktene deres i dag?
	Hvordan prissetter dere produktene i BIM-systemene?
	Hvordan tror dere at BIM kan påvirke deres selskap?
	Hvordan tror dere at BIM kan påvirke samarbeidet deres med en entreprenør?
	Har dere samarbeid med noen BIM-utviklere i dag?
	Hvordan påvirker samarbeidet med BIM-utvikleren selskapet deres?
	Hvilke tanker har du for fremtidig bruk av BIM-modellen for anskaffelsesprosessen?

Interview Guide – Architects and consulting engineers

Forskningsspørsmål: Hvordan kan BIM-modellen påvirke anskaffelsesprosessen i et byggeprosjekt for en entreprenør?
Innledning: Jeg skriver en masteroppgave hvor jeg ser på hvordan anskaffelse av materiale og håndtering av materiale på byggeplass kan påvirkes av en BIM-modell. Fokuset er på prosessen i dag, hvordan dere jobber med prosjekter, bruk av BIM i dag, og hvilke muligheter dere ser for dere videre. Målet med oppgaven er å kartlegge mulighetene man har med en BIM-modell og forstå hvordan modellen kan brukes til å forbedre dagens prosesser.

Tema	Spørsmål
Design fasen	Hvordan tegner dere en modell? Hva legges inn?
	Hvilke moduler har dere i deres modell? (Veggtyper, gulvtyper, materialinfo)
	Hvor mye info legger dere inn i modellen? Eks: Skille en yttervegg. Materialinfo
	Hvordan skiller dere på funksjon og ytelse? (vegg vs. u-verdi).
Samarbeid	Hvordan jobber dere med de andre rådgiverne? (Filutveksling og samhandling)
	Hvordan samarbeider dere med entreprenør?
Standardisering	Hvor mye kan gjenbrukes? Hva er standardisert? Hvem kan standardisere?
	Forholder dere dere til NS 8360? (BIM standard).
	Hva er utfordringer med standarder?
Ansvar	Kjenner dere til «BIM-Manual»? Hva er typisk krav fra oppdragsgiver?
	Hvilket ansvar har dere i forbindelse med at modellen får riktig informasjon (i henhold til BIM-manual)?
Produksjons fasen	Hvordan gjøres en endring? (Hvem må følge opp bæring av bygg etc.)
	Etterregistrerer dere innkjøpte varer?

Appendix 6 – Overview of Interviews

Subsidiary	Project	Project value	Project Status	Position	Age Group	Interview (type and length)
x	1	200-500 million	Construction	Project leader	35-50	Face-face, Approx. 1 hour
y	2	0-100 million	Construction	Project leader	51-65	Face-face, Approx. 1 hour
z	3	100-200 million	Construction	Construction Site Manager	25-34	Face-face, Approx. 1 hour
Architect	-	-	-	Employee	25-34	Face-face, Approx. 1 hour
Supplier	-	-	-	Leader	35-50	Face-face, Approx. 1 hour

Appendix 7 – Overview of meetings

Type of meeting (Topic)	Participants	Grounds
Supplier presentation - Digitalization and logistics	The researcher and five employees from the supplier; Director of IT, Director of Finance, Director of Logistics, Sales coordinator, Director of Purchasing	- Supplier explains why they are best in class with logistics
Project scheduling	The researcher, process manager from Backe and representatives from the subcontractors	- Observation of how the project is scheduled - Observation of how the subcontractors behave and how they cooperate
Software developer	The researcher, head of digitalization from Backe and general manager from the company	- Understand opportunities by implementing software technology - Discuss how Back could improve the procurement process with digitalization - Discuss standardization and how to extract information from the BIM-model
Tracking materials	The research and employees of a material tracking company	- Understand how tracking of materials works and what is required

The construction process	The researcher and the BIM-developer from Backe	- Understand the dynamics of the construction process - Discuss the barriers and possibilities of implementing BIM
Artificial intelligence	The researcher and an artificial intelligence developer	- Understand the opportunities with AI and how it can impact the construction process and BIM
Supplier presentation - Digitalization	The researcher, head of digitalization from Backe and two consultants from the supplier company	- Understand how the contractor can improve the construction process with digital data
Supplier presentation - 5D BIM and software	The researcher, CFO, CEO, head of digitalization, BIM-developer and process manager from Backe and the CEO of the supplier	- Presentation of the software the supplier had developed - Understand the possibilities of the BIM-model
NOBB Seminar	The researcher and 28 participants from the industry	- Discuss the digitalization development with BIM
Software course	The researcher and employees from subsidiary Z	- To learn how to handle one of the new software that was implemented in the company
Supervisor	The researcher and head of digitalization in Backe	- Discuss ongoing findings - Discuss the understanding of the construction process - Debrief after different meetings
Digibuild	The research group	- Discuss digitalization in construction

Appendix 8– Overview of documents

Type of document	Retrieved from	Grounds
Outline of the project	Project leader in subsidiary x	- Understand what information is provided from the design phase
Project schedule	Project leader in subsidiary x	- View how the project is scheduled
Workshop document	Project leader in subsidiary x	- Overview of how much time is planned for design, projecting and construction
BIM-manual	Intranet - related to project 1 and 3	Project-specific BIM-agreement document. Purpose of the document; - Responsibility for each of the project member - How to exchange data - Coordination of the model - The interface of the project team
Developer decision plan	Intranet - related to project 1	- View what decisions the developer needs to make in the design phase
List of suppliers with agreements	Intranet	- View which suppliers Backe has an agreement with
BIM-model	Intranet - related to project 1	-View what type of information is provided in the model
List of materials	BIM-model from project 1	- See what information the BIM-model can provide