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Digitalization in the construction industry

Potential industry dynamic changes in the construction industry caused by increased usage of building information modeling

Master of Science Thesis in the Management and Economics of Innovation Programme

ALEXANDER JENSSON

Department of Technology Management and Economics
Division of Innovation and R&D Management
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Supervisor: Dan Paulin, Technology Management and Economics
Supervisor: Stefan Carlsson, Triathlon Group
Examiner: Dan Paulin, Technology Management and Economics

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Department of Technology Management and Economics
Chalmers University of Technology
SE-412 96 Gothenburg
Telephone +46 31 772 1000

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Abstract

Background: The ongoing change towards digitalization and consequently BIM-usage in the Swedish construction industry may in many ways alter the industry dynamics. This future scenario is not well-anticipated among many industry actors and therefore there is an urgent need that every actor in the supply chain reacts to future opportunities and challenges when it comes to changes in roles, power positions, responsibilities and operational methods. Specifically, the decision-power over product choice in construction projects may shift (e.g. Which actor in the supply chain decides which pipe or radiator will be chosen and installed in a construction project?). **Purpose:** The purpose of this thesis is to explore the expected industry dynamic changes of potentially fully developed BIM-usage in the construction industry. **Approach:** This thesis was performed as an exploratory study combining both a deductive and an inductive research approaches where an assessment framework was developed based on previous literature and data was gathered through 16 semi-structured interviews with industry experts in the roles of managers, directors and CEOs representing different actors in the construction industry. **Results:** BIM-maturity vary among industry actors where the construction and engineering consultants are the most mature and manufacturing companies, wholesaling companies and installation companies have a lower BIM-maturity. Full utilizations of BIM might shift the decision power from installers to actors higher up in the supply chain namely construction companies, engineering consultants and owners/buyers. Identified moderators for a shift of decision point are increasing technical ability, information transparency, BIM-model ownership, project delivery methods and ineffective pricing within the construction industry. **Conclusions:** The findings lead to the hypothesis that a higher maturity of BIM within the construction industry shift the decision point of product choice upward the supply chain. Based on this hypothesis, the following industry dynamic changes could be expected in the future: Installation companies get a changed role, changed sourcing behavior amongst construction companies could affect the wholesaling companies' role, a shift in decision point could potentially shatter the kick-back culture between wholesaling and installation companies and new actors who provide BIM object online cloud will possibly play an important role in the future digitalized construction industry and likely take over parts of the decision power that wholesaling companies loose.

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Alexander Jensson, Gothenburg 2017

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1

Introduction

This chapter presents the thesis background, problem statement, research questions, academic contribution, scope and limitations.

1.1 Background

Industries and businesses have always strived to increase efficiency which has continuously pushed development of new operational methods and tools forward. During the last century, many operational methods and tools have been developed to pursue increased efficiency but only a few of these have become dominant. The assembly line can be considered as one of the most substantial operational methods that have become dominant within the manufacturing industry and its core attributes are still present in contemporary manufacturing methods. One of the most important technological tools that has been adopted within the engineering industry is computer-aided design (CAD). CAD is used to design and develop almost all products that surrounds us today. The technology has become increasingly advanced and incorporates a vast set of capabilities today. The assembly line and the CAD technology have fundamentally changed how companies perform their operations and how they are organized. It can even be argued that the introduction of the assembly line and the CAD technology have changed industry structures where some players have taken advantage of these emerging methods and technologies and successfully integrated them, whilst other firms have not adopted to the industry standards and consequently could not successfully compete.

One industry that has experienced a lack of efficiency improvement is the construction industry. This industry has only managed to reach approximately half of the efficiency improvements in comparison to other industries in the last 50 years (Hampson, Kraatz, and Sanchez 2014). The sub-optimal working process is caused by fundamental problems with time overruns, quality problems, conflicts between stakeholders and a low level of knowledge transfer between actors (Hampson, Kraatz, and Sanchez 2014). The problematic situation is commonly derived from inherent industry characteristics like the fragmented industry and building process with silos of interest and objectives, business models based on short term objectives, traditional static procurement contracts and inefficient information flow between actors (Akintoye, Goulding, and Zawdie 2014; Jonassen 2010; AIA 2007).

Unsuccessful collaboration and communication between actors in the supply chain is seen as the main reason for the overall industry inefficiency and the literature suggests that collaboration between key actors is a way of resolving the presented issues above. (Hardin and McCool 2015)

The lack of efficiency in the construction industry has been fueling the development of operational methods and technological tools with the purpose to streamline the industry and increase efficiency. Advancements in information and communication technologies have been at the core of this development in the recent decades and in the early 2000's Building Information Modeling (BIM) was introduced. BIM is considered a key technology to reach higher collaboration and thereby increased efficiency within the construction industry (AIA 2007).

BIM is a digital representation of physical and functional characteristics of a facility and has two different aspects. Firstly, it is the process of developing and using the digital model where the goal is to minimize the information gaps during the whole construction process. Secondly, it is the digital model itself that contains structured information about the construction throughout its lifecycle. The digital model contains objects which are often called "intelligent 3D components" or "BIM objects" that have data linked to them. (Hardin and McCool 2015)

Consequently, BIM is about gathering information in a structured way, making it available and visible in one single model where all project participants are continuously working, which enables easy communication and collaboration throughout the project (Eastman 2011). BIM makes early integration of project design and construction teams achievable through closer collaboration. This helps the comprehensive construction delivery process to become "faster, less costly, more reliable, and less prone to errors and risk" as described in (Eastman 2011).

BIM is adopted at a high speed and is in some countries even pushed through by government policies. American contractors, engineers and architects has gone from 28% in 2007 to 74% in 2012 (Hardin and McCool 2015) and UK government introduced a policy in 2011 stating that they demanded fully collaborative BIM on their construction projects by 2016 (UKCO 2011). The outcome of this policy is not yet measured but the policy itself denotes an important breaking point for BIM adoption worldwide and there are many indications that usage of BIM tools and processes is approaching a tipping point (Succar, Sher, and Williams 2012). It can therefore be argued that BIM is becoming the dominant operational method and technological tool in the construction industry and that it will govern the way that construction projects are designed, planned and executed in the future.

1.2 Problem statement

The construction industry is moving towards a higher degree of digitalization and usage of BIM (Eastman 2011; Hardin and McCool 2015) and BIM is considered as the new "CAD paradigm" by the industry as well as the academia (Ibrahim, Krawczyk, and Schipporeit 2004). The ongoing change towards digitalization and consequently BIM-usage in the Swedish construction industry may in many ways potentially alter the industry dynamics where current roles may change, power positions between actors may shift, new operational methods may emerge, actors' responsibilities may be adjusted and new actors with new roles may potentially emerge. As digital changes often develop rapidly and unexpectedly, all actors within the industry need to prepare accordingly for the above-mentioned changes and their specific new roles.

This future scenario is not well-anticipated among many industry actors and therefore there is an urgent need that every actor in the supply chain reacts to future opportunities and challenges when it comes to changes in roles, power positions, operational methods and responsibilities. Specifically, the decision-power over product choice in construction projects may shift (e.g. which actor in the supply chain decides which pipe or radiator that will be chosen and installed in a construction project?). If not well-predicted, manufacturers will face struggles as they have the strongest tie to the decision maker of product choice. In order to stay competitive, the manufacturer need to early on anticipate their new roles triggered through digitalization and BIM-development as they need to understand which capabilities to develop, which actors to influence and what to produce.

1.3 Purpose and Research Questions

The purpose of this thesis is to explore the expected industry dynamic changes of potentially fully developed BIM-usage in the construction industry, which is done by undertaking three sub-steps. The first step assesses the current status of BIM-maturity for all actors in the construction industry. The second step poses the future scenario of full BIM-usage throughout the whole industry and assesses what the expected effects would be on decision point of product choice between the industry actors, i.e. which actor decides on what product that is chosen for a construction project. The last step examines the potential reasons (moderators) for a shift in decision point. This leads up to the main research question with sub-questions:

1. What are the expected industry dynamic changes of potentially fully developed BIM-usage in the construction industry?
    1.1. What are the current status of BIM-maturity for all actors in the construction industry?
    1.2. What are the expected effects on decision point of product choice between the industry actors?
    1.3. What are the potential moderators for a shift in decision point?

1.4 Scope & Limitations

The scope of this thesis is limited to the technical installation sub-industry of the construction industry where the focus areas are installations of piping and electrical products in buildings.

2

Literature review

This chapter presents findings from the literature review which was used to create the assessment framework for this thesis and to consolidate the analysis and discussion. The fist sub-chapter describes an industry dominant production method and an industry dominant technological tool; the second sub-chapter describes building information modeling from different aspects; the third sub-chapter describes the construction industry supply chain; the fourth sub-chapter describes project delivery methods; the fifth sub-chapter describes the decision making chain of choosing products to construction projects and the last sub-chapter describes construction industry lifecycle phases and BIM-maturity stages.

2.1 Industry dominant production methods & technological tools

During the last century, many production methods and technological tools have emerged and some of these have even become dominant within specific industries. These methods and tools have fundamentally changed the way companies perform their operations. These have changed industry structures to the extent where players have entered and exited the market place. This chapter will firstly introduce a production method that has become fundamentally dominant in the manufacturing industry. Secondly, a technological tool that has become fundamentally dominant in the engineering industry will be presented. Thereafter, improvements of the production method and the technological tool will be described and lastly future development will be discussed.

2.1.1 Fundamentally dominant production method

In the beginning of the 20th century a production method called progressive production, more known as the assembly line, emerged. The assembly line enabled the second industrial revolution, often referred to as mass production (Hounshell 1984). The major development of the assembly line can be attributed to the Ford Motor company (Nye 2013).

The development of the assembly line was not planned, it rather emerged from a combination of existing practices and ideas of various industries and contexts of cumulative technological knowledge. Productivity increase was the force that pushed the development of this new production method (Nye 2013)

An important influence in the development of the assembly line came from the meat packing industry in Chicago. The Swift & Company's slaughterhouse used a method called the disassembly line where cadavers were butchered as they were transported along a feeder band. Along the feeder band personal performed the same standardized task time after time, making the disassembly line very effective. (Ford 1922)

The core ideas that was employed at Swift & Company inspired the Ford motor company and influenced the development of the assembly line. The assembly line come to consists of five essentials according to (Nye 2013): "subdivision of labor, interchangeable parts, single-function machines, logical sequences of machinery layout, and slides and belts for moving tasks to workers"

The assembly line became the dominant production method within the automotive industry because of the tremendous productivity increase and consequently decrease in production cost per unit. The production method was widely adapted among the leading companies operating within the automotive industry. (Klepper and Simons 1997)

These companies were in the front-line of process innovation and focused on continuously improving the process which lead to even lower costs and greater output, hence generating economies of scale. The established companies thereby gained major competitive advantage, resulting in a higher market entry barrier. Companies who did not successfully adopt the production method lagged behind and were ultimately forced to exit the market. (Klepper and Simons 1997)

The production method was so productive that very few things very produced without the assembly line after that. The assembly line spread to a wide range of industries and was copied to factories producing "foods, consumer appliances, household and office equipment, tools, bicycles, toys, and games". The core idea of the assembly line was even adopted beyond the manufacturing industry to fast food chains, cafeterias and supermarkets. (Nye 2013)

There has arguably been two major improvements of the assembly line since its introduction - incorporation of the lean manufacturing philosophy and later automation technology. The lean manufacturing philosophy, introduced by Toyota in Japan, perfected the assembly line and doubled the productivity by putting the worker in center (Nye 2013). Giving more responsibility to the individual worker lead to higher involvement and engagement, incrementally increasing quality and productivity step by step. Gradually, different kinds of robots have been integrated into manufacturing, making the assembly line progressively automated. From the start, robots were put on the assembly line to perform heavy, dirty or hazardous tasks but in recent times robots perform increasingly complex tasks requiring extreme precision. Today's manufacturing facilities require less personal and automation has totally changed how products are produced and assembled. (Groover 2008)

The current trend within automated manufacturing is often referred to as industry 4.0 i.e. the fourth industrial revolution (Pfeiffer 2017). Highly flexible and productive smart factories are at the core of industry 4.0's vision. Smart factories are production systems that incorporate smart and network-connected machines that are interconnected using information and communication technology. Processes are controlled based on big-data analysis which allows for highly-automated and adaptive value chains that can react in real-time. The analytic results can be applied to everything from planning and production improvements to product development. (Gilchrist 2016)

The assembly line has gone through a tremendous change over a 100 years but despite this change, contemporary production methods still employ the same fundamental ideas originating from the assembly line. Parts are standardized, work is subdivided and tasks are performed in a sequential manner. (Nye 2013)

In conclusion, the assembly line has left an important imprint on the manufacturing industry and that it can be seen as an innovation which modern manufacturing stems from.

2.1.2 Fundamentally dominant technological tool

Computer-aided design (CAD) is a technological tool that uses computers to aid creation, adjustment, simulation and optimization of a design. It was developed to increase the speed of the traditional design processes (Brown 2009).

The history of the first CAD systems stretches back to the mid 1960's. CAD began to gain attention at large automotive and aerospace companies because of the productivity improvements it promised (Lichten 1984; Weisberg 2009). Development of CAD programs for commercial use were initiated in the early 1970's and throughout this decade the CAD industry grew to a billion dollar hardware and software industry dominated by a few large companies (Weisberg 2009). Major advancements in hardware and software development in the 1980's and 1990's with introduction of the personal computer and dominant operating systems, made CAD hardware and software cheaper, faster and increasingly available to a wider market (Weisberg 2009).

CAD has revolutionized the engineering industry and fundamentally changed the product development and design process. CAD can today be considered a cornerstone for how one designs, develops and builds products within but also outside of the engineering industry (Brown 2009). CAD has an impact on an organizational level by changing the role of the engineer in design where draftsmen, designers and engineering roles has merged (Weisberg 2009). Similarly expressed by Rader, Wingert, and Riehm (1988) - CAD reorganized firm by bridging the gap between product development and design. At an industry level, CAD has been tremendously effective and necessary technological tool that engineers have used to maximize efficiency and speed up the product development process (Brown 2009). For these reasons, it can be concluded that CAD has become a dominant technological tool within the engineering industry and has changed how companies operate and how they are organized.

Development of CAD in the recent year has centered around incorporating a variety of analytical tools used for solid mechanics calculations with finite element methods or fluid dynamic calculations with computational fluid dynamic methods. Collaborative software environments have also been emerging, triggering to consolidate the product development process within large corporations and make it even more effective. (Radhakrishnan et al. 2008)

Discussions about future developments of CAD software include cloud-based software, incorporating virtual and augmented reality and using artificial intelligence for generative design. (Hirz, Rossbacher, and Gulanová 2017)

In conclusion, CAD has been the dominant design since a long time and with incremental improvements it has made the design and product development process more and more effective.

2.2 Building information modelling

The construction industry have had efficiency, productivity and quality problems throughout the history which in many cases has resulted in budget and time overruns. This situation has triggered digitalization, advancements in information and communication technologies plays an important role streamlining the industry. Building information modeling (BIM) is a rapidly growing technology and operational method which is considered to be a key technology that has great potential to address the industry issues. (AIA 2007; Azhar, Hein, and Sketo 2008)

2.2.1 Defining BIM

At a high level, building information modeling (BIM) is a set of technologies, processes and policies (TPP) that together composes a new way of managing building design and project data in a digital format throughout a building's life-cycle (Penttilä 2006; Succar 2009). Each of these TPP fields has its own players which can be individuals, teams or organizations (Succar 2009).

Technology. This field encompasses a collection of players who specialize in software, hardware and network solution development that assists the architecture, engineering, construction and owning (AECO) sectors in the pursuit of increased efficiency, productivity and profitability. (Succar 2009)

Process. This field encompasses a collection of players who performs the processes of designing, constructing, manufacturing, using and maintaining buildings and structures. The players in this field include the AECO industry players as well as players involved in ownership, delivery and operations of buildings and structures. (Succar 2009)

Policy. This field encompasses a collection of players who assist the AECO industry by preparing practitioners, performing research, allocating benefits and risks and minimizing risks and conflicts. The players in this field include insurance companies, research centers, educational institutions and regulatory bodies. (Succar 2009)

More specifically, BIM serves as a digital representation of physical and functional characteristics of a facility (NIBS 2007). The physical characteristics are what you can see, i.e. the objects and the model as a whole. The functional characteristics are the displayed functions that the objects and models can perform e.g. heating, ventilation and air condition (HVAC) and electrical systems.

There are two different aspects of BIM and the term "BIM" is often described accordingly. Firstly, it is a working process of developing and using the digital model where the goal is to minimize the information gaps during the whole construction process. This is done by collaboration between different key participants that can add, retrieve and update data in the model. Secondly, it is the digital model itself that contains structured information about the building throughout its lifecycle. The digital model contains objects which are often called “intelligent 3D components”. These objects have data linked to them. (Hardin and McCool 2015)

Consider a water piping system for example as in figure 2.1. The BIM-object of this piping system would be a digital representation of the physical product with its dimensions as well as functional characteristics attached to it such as waterflow capacity, isolation metrics, materials and assembly information. This model is built up and used to plan, design, construct, operate and maintain a building.

Figure 2.1: BIM-model and construction project1

The models have several different dimensions of project information. (BSI 2010) defines these data dimensions as 3D, 4D, 5D and nD. The third data dimension represents the visual aspects of the model and objects included in the model (the visual aspect of the digital model in figure 2.1), the fourth data dimensions represents the time aspect (how the digital model in figure 2.1 change over time), the fifth data dimension includes cost information (cost information of the components in figure 2.1) and the n:th data dimension represents all additional information that can be included in the model or in the individual objects. (BSI 2010; Eastman 2011).

The 3D information is used to assess the constructability of a building before the project is carried out. Design errors, conflicts and clashes can be detected and mitigated beforehand. This working procedure ensures an efficient construction process and maximizes the possibility of carrying out a construction project on time and within the budget. (Eastman 2011; Hardin and McCool 2015)

The 4D information enables visualization of the building model over time by simulating the construction process. This information is used to plan construction activities and sequences as well as placement of machinery and material at the construction site. (Eastman 2011; Hardin and McCool 2015)

The 5D information enables early budget estimations with high level of detail and accuracy. This information can be used to evaluate financial performance throughout the project and thereby create a good foundation for decision making. (Eastman 2011; Hardin and McCool 2015)

2.2.2 Collaborative aspect

As described above, building information modelling is a process and technology that enables virtual construction of a building before its realization. In order to gather all information and knowledge into the model, several key participants are involved in the early design phase of the construction project to virtually design and construct the building. BIM supports the collaborative aspect where all the participants have access to the model and can add, extract and modify data. (Hardin and McCool 2015; Nawari and Kuenstle 2015). The collaborative aspect is illustrated by Nawari and Kuenstle (2015) and presented in figure 2.2.

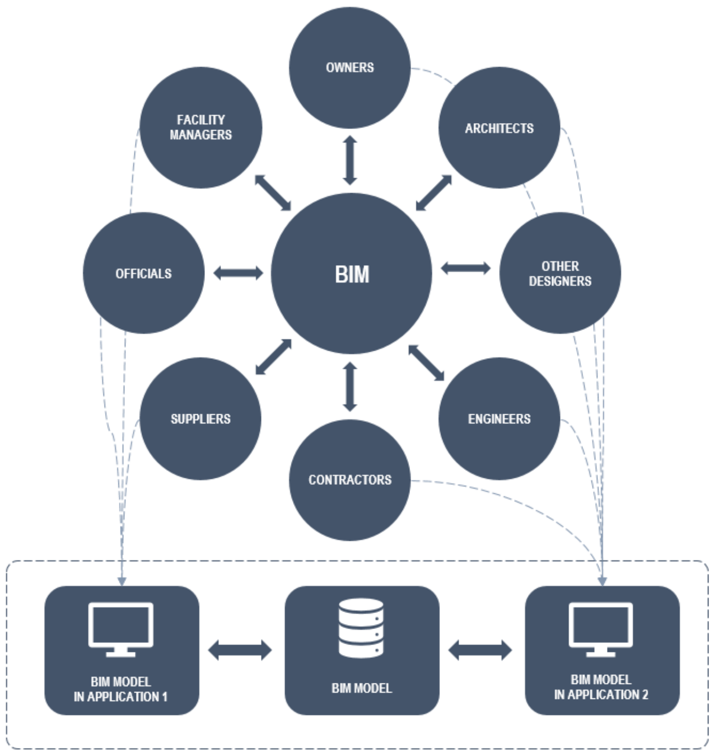

Figure 2.2: Schematic representation of collaborative aspect of BIM

2.2.3 Increased technical ability with BIM

Using BIM offers a great gain in technical ability i.e. what becomes possible to do that was not possible before, for all project participants. The technical ability increase can be seen in four different aspects: information management, visualization, simulation and evaluation.

Information management. Construction projects are dependent on accurate and easily accessible information. Through BIM, all information and knowledge are gathered in one model. Compiled digital documentation about time-plans, drawing, specifications, cost-estimations or assembly instructions become easily accessible. They can be viewed and shared digitally with BIM. (Kensek and Noble 2014)

Visualization. The visualization aspect of BIM enables stakeholders to better understand designs and proposals which is an important factor of decision making (Granroth 2011). The most obvious visualization aspect is the physical clash and collision control that can be assessed in the BIM model (Eastman 2011)

Simulation. Simulation of functional systems such as HVAC and electrical systems provide the means for optimization that enable a more accurate installation setup (Kensek and Noble 2014).

Evaluation. Information about time-plans and costs can continuously be evaluated against actual spending and time-consumption which provides important data for decision-making (Granroth 2011; Eastman 2011).

2.2.4 Difference between CAD and BIM

BIM is considered as the new paradigm of CAD both in the industrial and academic sphere (Ibrahim, Krawczyk, and Schipporeit 2004). But what is the difference between CAD and BIM? There are two major differences between conventional CAD and BIM (Azhar, Hein, and Sketo 2008).

Purpose of technology and the work process. CAD is used to independently describe a building through individual 3D objects and 2D views such as plans, sections and elevations (Azhar, Hein, and Sketo 2008). BIM is used to create a virtual building which is built up by computable information in objects (Eastman 2011). The work-process using CAD or BIM is therefore significantly different. The CAD drawings must be updated individually since the documents independently describe the building and, in contrast, one specific BIM object can be modified and is then automatically updated throughout the BIM model which is then used to visualize the building (Azhar, Hein, and Sketo 2008).

Object attributes and parametric data richness. CAD drawings are merely graphical objects made up by dots, lines, arcs and circles with no attributes attached to identify what the drawing actually represents. BIM models on the other hand consists of attributed objects such as walls, roofs and HVAC-systems. (Azhar, Hein, and Sketo 2008). These attributed objects are programmed to have specific physical and functional properties equal to the real product that they represent, called semantic-richness by (Succar 2009). This can be for example a piping-system that has a certain flow-capacity, isolation-value, material and physical dimension in a BIM model and is not only represented by graphical objects as in the CAD drawing (Ibrahim, Krawczyk, and Schipporeit 2004). In addition to the information about physical and functional properties described above, BIM objects also contain information about who these are related to other aspects, called parametric data. This is information about cost, operation, maintenance, etc. (Azhar, Hein, and Sketo 2008)

2.2.5 Manufacturers' role in BIM

Data is at the core of BIM and a building's features are strongly connected to the characteristics of the products that are installed in the building. In order to fully utilize the promises of BIM, everyone in the construction industry supply chain need accurate and correct product data. The most reliable data source is the actor who develops the information i.e. the manufacturer of building products. (Fredenlund 2016) With this reasoning, the manufacturer of building products plays a central role in the BIM network.

It is also important to note, that the manufacturing industry has been adopting and embracing new technology throughout recent history to a much larger extent than the construction industry. Even though manufacturers of building products operate within the construction industry, their core business is more aligned with the manufacturing industry. The majority of all manufactures use digital tools for designing, testing and manufacturing their products today. This means that the manufacturers already have access to the information that makes up the BIM objects, but in a varying degree of structure. (Charlton 2013)

There are several potential benefits for manufacturers and according to Eastman (2011), page 306, these include: "enhanced marketing and rendering through visual images and automated estimating; reduced cycle times for detailed design and production; elimination of almost all design coordination errors; lower engineering and detailing costs; data to drive automated manufacturing technologies; and improved preassembly and prefabrication."

2.2.6 BIM adoption

Adoption of BIM in north America among contractors, engineers and architects has gone from 28% in 2007 to 74% in 2012 (Hardin and McCool 2015). The UK government construction strategy was published in 2011 and stated that they demanded fully collaborative BIM on its projects by 2016 (UKCO 2011). The outcome of this policy is not yet measured but the policy itself denotes an important breaking point for BIM adoption worldwide. There are many indications that usage of BIM tools and processes is approaching a tipping point (Succar, Sher, and Williams 2012).

2.3 The supply chain

The supply chain includes all activities, organizations, information and resources connected to the flow and transformation of a good from raw material to end customer. Information and material flows can go both ways in the supply chain. (Ballou 2004) A schematic representation of a generic supply chain is presented in figure 2.3.

Figure 2.3: Supply chain

2.3.1 Construction industry supply chain

The construction industry supply chain is rather complex and consist of several different actors. Actors are involved in specific stages in the supply chain. Moreover, from a project perspective, the construction industry can be considered to have four distinct stages; product manufacturing, design & engineering, construction and operation & maintenance. The first stage involves manufacturers; the second stage involves building buyer/owner, architect and engineer; the third stage involves contractor, sub-contractor, architect and engineer and the last stage involves maintenance company, building occupant and building owner. Wholesalers consolidate the product/material flow between the actors and over the stages. The actors involved in a construction project can vastly vary depending on factors such as projects scale, project delivery method and buyer/owners preferences (Groote and Lefever 2016). Figure 2.4 represents a simplified supply chain for the construction industry including the actors involved in the distinct stages. This representation is based on the research of UKCO (2013) and Groote and Lefever (2016).

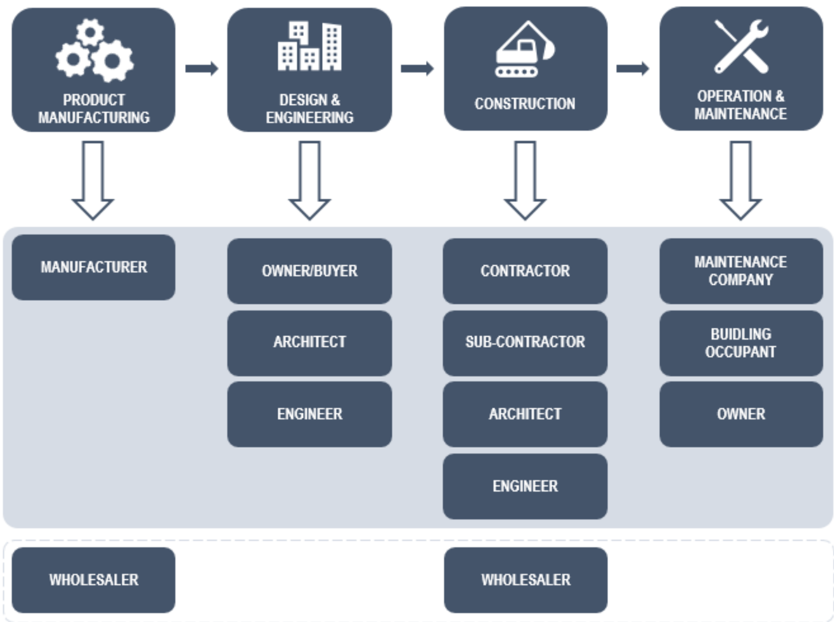

Figure 2.4: Construction industry supply chain

2.4 Project delivery methods

Project delivery methods are ways by which design and construction of buildings are purchased and delivered. Different project specific attributes often determine which method to use where project complexity, knowledge, modification flexibility and risk assessment among other factors is taken into consideration. The two most common project delivery methods are design-build (DB) and design-bid-build (DBB) but in recent years, more collaborative project delivery methods such as Integrated project delivery (IPD) has becoming increasingly common. Firstly, these different project delivery methods are described and secondly these methods are discussed in relation to building information modeling. (AIA 2007)

2.4.1 Design-build (DB)

The buyer/owner enters a contractual agreement directly with one actor that takes on both the design and build responsibility. This actor is most commonly a contractor that either has design capabilities or takes in the design capability from a separate actor. The contractor develop a design concept in line with the buyer/owner outspoken needs and makes time and cost estimations for designing and constructing the project. At this point an iterative process starts where the buyer/owner reviews the contractor's proposal and either makes modifications or accepts the concept. Hence, the buyer/owner has a highly integrated role in the initial design process. When the concept is accepted, the contractor establishes contracts with specialized designers and subcontractors in order to fully design and construct the project. (AIA 2007) The design-build delivery method is visualized in figure 2.5.

Early collaboration between buyer/owner and contractor in the design phase enables a more thorough design where alternations and modification to the concept are done at an early stage which can potentially decrease spending and reduce time needed in the construction project. This project delivery method is mainly chosen because the entire responsibility and risk are transferred to one actor. The contractor is responsible for design changes, obstacles and errors form the concept acceptation point. The responsibility and risk transfer can also be considered as a drawback since it decreases the buyer/owners influence of making changes later in the project and the project delivery method can therefore be seen as inflexible in this aspect. (Eastman 2011)

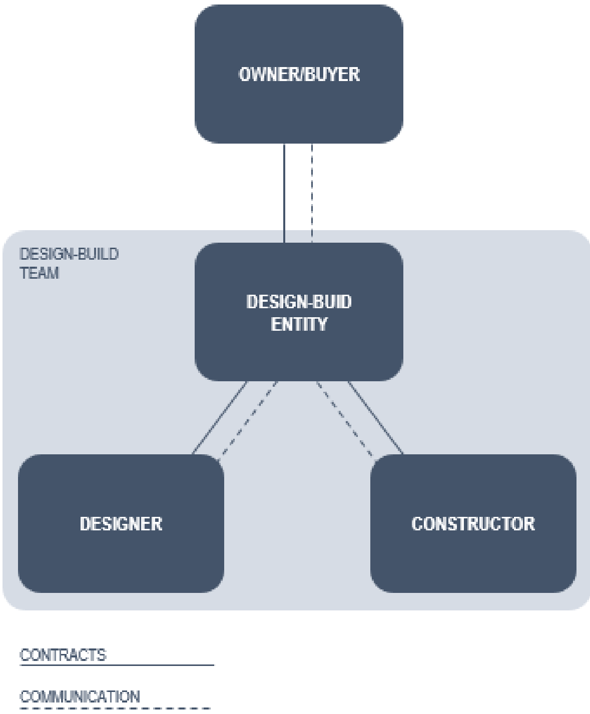

Figure 2.5: Design-Build delivery method

2.4.2 Design-bid-build (DBB)

This project delivery method is often referred to as the traditional procurement and is the most common way of procuring construction projects. In the design-bid-build procurement, the buyer/owner enters a contractual agreements with the designer and the contractor separately. As the name hints the different stages design, bid and build are separated. First the buyer/owner enters a contractual agreement with a designer that oversees the development of project requirements and construction design. Thereafter, the developed design undergoes a bidding phase where the buyer/owner decide on one contractor that will be in charge of the construction phase. (Eastman 2011) The design-bid-build delivery method is visualized in figure 2.6.

The main reason why this project delivery method has been, and still is, the most common way of procuring construction projects is because the buyer/owner benefits from an open market competitive bidding process to achieve the lowest possible price (AIA 2007).

A drawback with the DBB project delivery method is that the project design is to a very low degree influenced by the actors who carry out the actual construction work. Construction details that could lead to coordination problems are therefore not visualized and dealt with initially in the design phase, but rather pushed to the construction phase, which often lead to delays and budget overruns. (Eastman 2011).

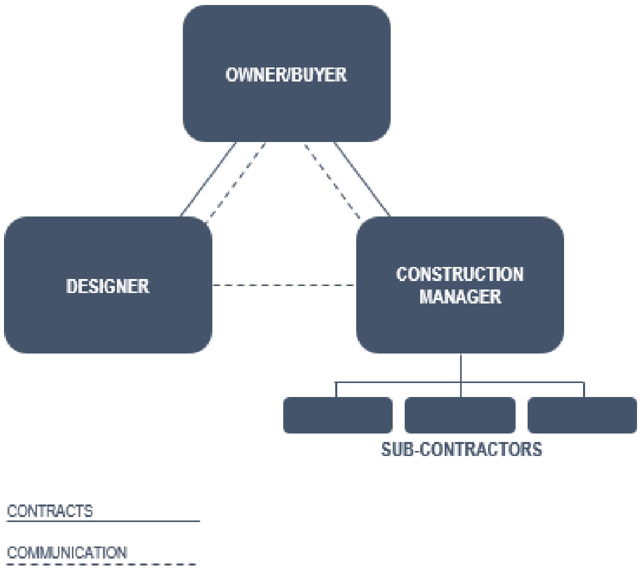

Figure 2.6: Design–Bid-Build delivery method

2.4.3 Integrated project delivery (IPD)

The IPD project delivery method is relatively new to the construction industry, but is increasing in usage and popularity (Eastman 2011).

There are many different approaches to IDP but the core is focused on effective collaboration between several industry actors. These actors are key project participants and are commonly buyer/owner, primary designer and primary contractor. The collaboration can in some cases also stretch further and include sub-designers and sub-contractors. (AIA 2007)

The collaboration starts early in the design phase and continues throughout the entire project (Eastman 2011) and the involved actors are temporarily working as an organization with shared goals and aligned incentives. The success of an individual participant is therefore dependent on the other participants which creates a tighter team and a higher degree of collaboration between the actors involved in the construction project (AIA 2007). All actors are sharing both benefits and risks and divides profits and share losses, according to the project outcome (Parrott and Bomba 2010).

The collaborative aspect of IPD is aimed to meet buyer/owner requirements at lower cost and within a shorter time frame. As described above, this is mainly done by aligning participants' interest which facilitates collaboration.

Forming the temporary team can be a costly process where the terms have to be agreed upon, especially if participants have low level of prior experience of the IDP approach. The highest benefit of IDP can be achieved in larger projects where the initial investment of aligning interests and incentives can be covered to a higher degree (AIA 2007).

2.4.4 Project delivery methods and BIM

The three presented project delivery methods have different level of suitability in combination with building information modeling. The DBB project delivery method is considered the least suitable because of its fragmented process with distinctly separated design, bid and build phases. The DB project delivery method is more suitable since the design is iteratively agreed upon between the buyer/owner and the main contractor. The most suitable project delivery method in combination with building information modeling is IPD. (AIA 2007)

The IPD procurement rout has the highest level of collaboration and takes advantage of key participants knowledge and are aligning needs and incentives early in the design phase (Eastman 2011). BIM is considered a key technology to reach higher collaboration, integration and interoperability and thereby increased industry efficiency within the construction industry (AIA 2007; Succar 2009; Grilo and Jardim-Goncalves 2010; Isikdag and Underwood 2010). Research suggests that the development of IDP is both fueling and being fueled from the adoption of building information modeling (Eastman 2011). According to the government strategy document from the UK, the public sector will become a more informed and coordinated client regarding when requirements are specified, designed and produced (UKCO 2011). In line with this promise, the strategy also sets out goals for innovation in the industry business models and practices where they demand that adversarial cultures must be replaced with collaborative ones in order for companies to maintain market position (UKCO 2011). It can therefore be concluded that the adoption of BIM and shift towards project delivery methods that facilitates collaboration such as IPD goes hand in hand and that the collaboration between buyer/owner, designer and contractor will most probably be the future of carrying out construction projects (Eastman 2011).

2.5 Decision making chain

Products that end up in construction projects are picked and specified by different actors in construction industry supply chain. In today's industry climate, it is rather unusual that a single actors have full control of the decision to purchase a specific product from a certain manufacturer. The influence of selecting or preventing selection of a product are more commonly spread over many actors (PCUK 2014; Ashworth 2016). The dynamics of this process is described by a five step decision making chain, which is presented below and in line with Eastman (2011) description of the traditional DBB project delivery method. A schematic representation of the decision making chain is presented in figure 2.7.

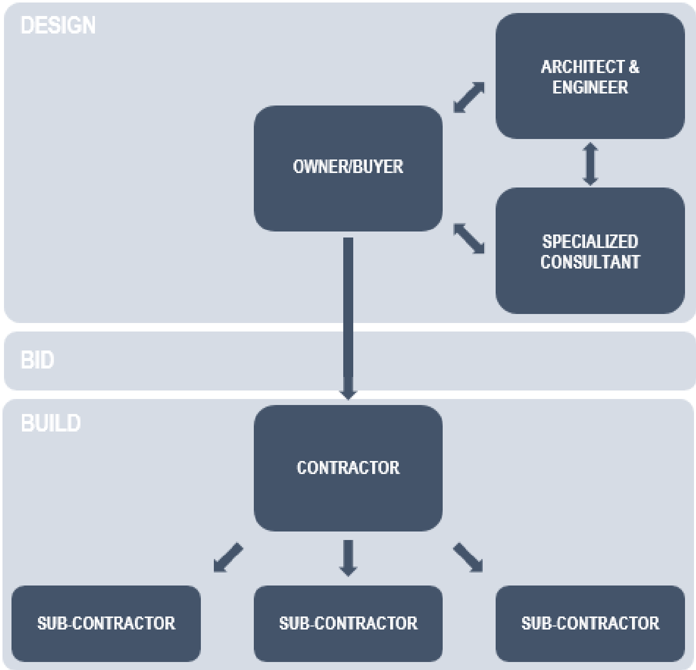

Figure 2.7: Decision making chain for the traditional DBB project delivery method

Buyer/Owner defines the building brief. At this stage functional needs that include some visual and performance factors are defined. Even though no specific products selection usually are made at this stage, these actors has significant influence over the final product that is going to be used. (Eastman 2011; PCUK 2014; Ashworth 2016)

Specialist consultants input. At this stage specialized consultants offer guidance in addition to the building brief and specifies more detailed performance requirements. There are rarely any specific product specified at this stage. (Eastman 2011; PCUK 2014; Ashworth 2016)

Architect and Engineer define the design. The architect gathers and combines the information from the initial building brief and the specialized consultant's requirements in order to develop the building design. Depending on the nature of the construction project, engineers responsible for structural, mechanical and electrical design are also involved at this stage. All these actors have a great influence on specifications and therefore also selection of specific products. (Eastman 2011; PCUK 2014; Ashworth 2016). There are four factors that these actors consider when evaluating a product-choice: product, manufacturer, installation and costs. E.g. Does the product have the appropriate functionality and aesthetics characteristics? Are the manufacturer reputable and can provide correct information, good service, long warranties and a reliable delivery? Is the product installable in the specific situation and are there skilled workers that can perform the installation? What are the product, installation, operation and maintenance costs? (CSI 2011)

Main contractor. The main contractor is usually responsible for product selection to some extent and are indirectly influencing the product selection process by selecting specialist sub-contractors. (Eastman 2011; PCUK 2014; Ashworth 2016)

Sub-contractors. The sub-contractors can be responsible for the final product selection, depending on the description of the architect's or engineer's specification made at an earlier stage. There are usually four different specifications methods: descriptive, performance, reference standard and proprietary. The first two only describes a functional or performative aspect of a product; the second describes a specific product connected to a reference standard with the possibility to choose an equivalent product and the last one description of a fixed specific product. (CSI 2011) In the first two cases, the sub-contractor has great influence over product choice. The sub-contractor values technical product support, brand-familiarity, installation-speed, availability and price (Ashworth 2016).

It is important to consider which project delivery method a construction project is procured through since it affects the decision-making chain described above. Decisions about products are far more complex in the construction industry than in other business-to-business situations because of the temporary constellation of actors working in a construction project. (Eastman 2011; PCUK 2014; Ashworth 2016)

A report from the consultancy Roland Berger hypothesizes that an increasing use of BIM might shift decision-making structures. Up until now construction companies and sub-contractors have sourced building material from manufacturers that they find suitable based on the specification provided from architects and engineers. In a near future, however, architects and engineers will not only do specifications but also choose manufacturers because of an increasing usage of BIM in their planning. The construction and sub-contractor companies will possibly move further in the direction of only carrying out the specified work with very limited influence of how it should be done and which products and materials to use. (Schober and Hoff 2016)

2.6 Construction project lifecycle phases & BIM maturity stages

Construction project go through three major stages in their life-cycle: Design and Engineering (D&E), Construction (C) and Operation and Maintenance (O&M). Historically these phases has been performed in a linear sequential manner where design and engineering comes first, construction second and operating and maintenance last, see figure 2.8. "BIM implementation in the construction industry will possibly change the components of and relations between lifecycle phases, activities and tasks. These changes are caused by varying BIM interactions between actors in the industry and BIM maturity". (Succar 2009)

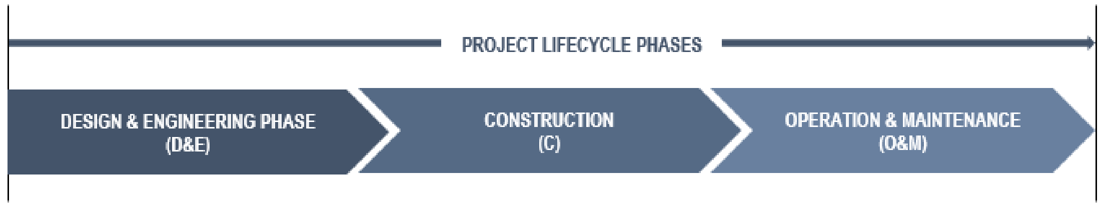

Figure 2.8: Construction project lifecycle phases

2.6.1 BIM maturity stages and the potential change of project lifecycle phases sequences

Below follows a description of BIM maturity stages and how these stages are linked to changes in the project lifecycle phases originally presented by Succar (2009).

Pre-BIM. The construction industry in the pre-BIM maturity stage is characterized by non-collaborative relationships between industry actors. The contractual agreements that they enter into are only focusing on risk prevention. The actors are dependent on 2D documentation that describes the non-2D world and there are no quantity, cost or other specification data that can be collected from a virtual model. (Succar 2009) Work flow of the project lifecycle phases (D&E, C and O&M) are linear, see figure 2.8, and there is a clear lack of interoperability between the stages (Dawson 2004; Gallaher, Dettbarn, and Gilday 2004).

BIM-stage 1. The implementation of BIM is in its initial phase and companies start to use object-based 3D parametric software tools. Actors within the individual lifecycle phases (D&E, C and O&M) generate their own models with deliverables primarily intended to generate and coordinate 2D documentation and 3D visualization. There are in other words no substantial model-based interactions between actors and lifecycle phases but rather simple data exchange between the lifecycle phases interfaces, see figure 2.9. But since there are relatively modest process changes in comparison to the pre-BIM stage, contractual relations, risk allocation and organizational behavior do not change in particular. (Succar 2009)

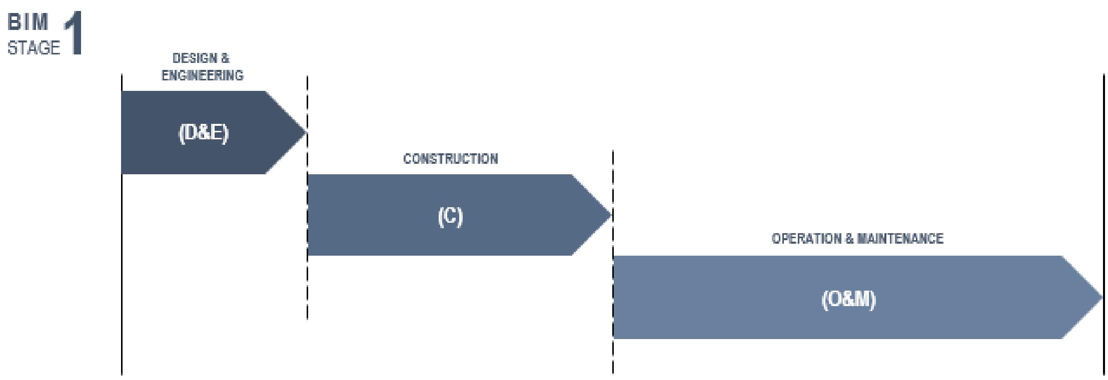

Figure 2.9: Sequence of lifecycle phases at BIM-stage 1

BIM-stage 2. Actors within the lifecycle phases collaborate actively. The collaboration can be either more advanced interoperable model-based collaboration or part-model exchange as in the interfaces between phases described in BIM-stage 1. Collaboration can be performed within or between lifecycle phases and one single model can hold all information in order for the actors to generate 4D time planning and 5D cost estimation etc. The collaborative aspect of this maturity level allows for project lifecycles to overlap, see figure 2.10. This is driven by construction actors incorporating design-related services into their business and by the design actors incorporating construction and procurement information into their design models. Additionally, the accuracy and amount of information included in the models are reaching a high level and starts to replace the more generic structural and mechanical designs that previously were included. (Succar 2009)

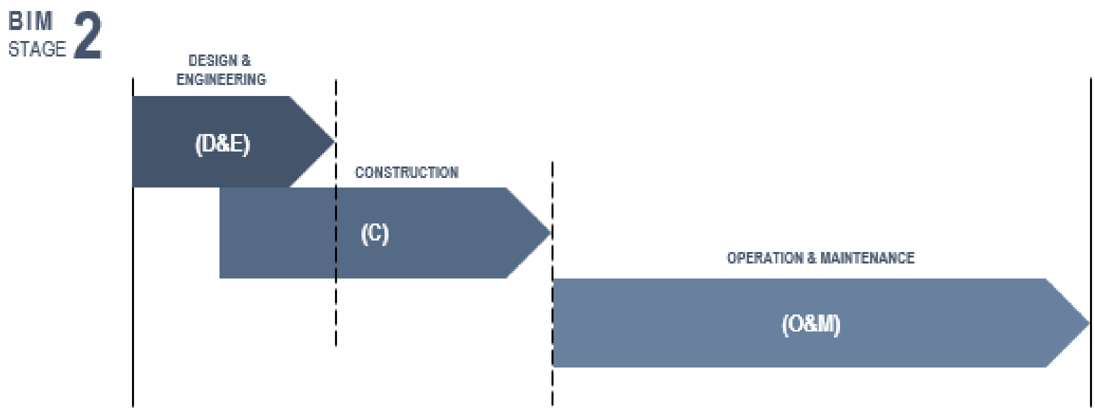

Figure 2.10: Sequence of lifecycle phases at BIM-stage 2

BIM-stage 3. BIM-models with high accuracy and detail level are created, shared and maintained in a collaborative manner throughout all project lifecycle phases. These models incorporate n-dimentional (nD) information which allows for complex analysis and evaluation of the virtual design and construction (Lee et al. 2003). The nD information includes 3D visualization, 4D time visualization and 5D cost information (Eastman 2011). Actors within all lifecycle phases work collaboratively in the same data model (Edgar 2016). The interaction and interchange between actors in the data model enables all project lifecycle phases to overlap creating a seamless process without phase distinctions, see figure 2.11. Actors reaching BIM-stage 3 has to reconsider contractual agreements, risk-sharing models and operational workflows (Succar 2009).

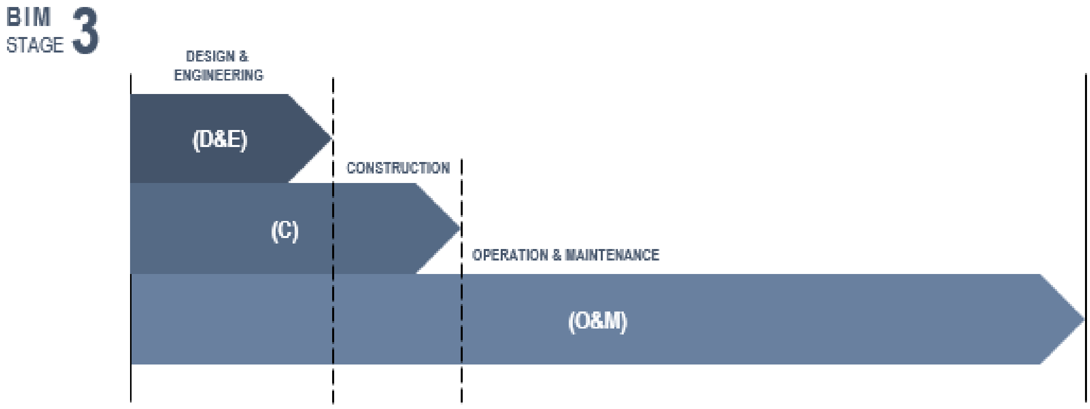

Figure 2.11: Sequence of lifecycle phases at BIM-stage 3

3

Assessment framework

This chapter describes the assessment framework that was created and used in this thesis. The framework was developed based on insights gained from the literature review. The framework has served three purposes throughout the project: it was used as a guide for the interviews, it was used to structure the results and it served as the foundation for both the analysis and the discussion.

3.1 Industry actors

Several interviews have been performed with a range of industry actors in this study. These actors were identified while reviewing literature about the construction industry supply chain. Since the focus of this study was on the installation sub-industry of the construction industry, the following actors were chosen: construction companies, engineering companies, wholesaling companies, installation companies (subcontractors) and manufacturing companies.

3.2 Current situation

This section describes the assessment of the current situation. It addresses the current situation of each actor in two aspects: maturity level of BIM and decision point of product choice.

Maturity level of BIM. This aspect evaluates each individual actor's maturity level of BIM. The maturity level assessment is based on Succar (2009) research and measures maturity of the three BIM-fields technology, process and policy. Questions and description connected to each field support the decision of a specific maturity level and provides a score. A median score was calculated where the level of maturity was put on a scale form 0 to 50. The BIM maturity framework that was used in the interviews can be found in appendix A.

Decision point of product choice. This aspect evaluated the individual actor's perception of where the decision point of product choice is located in the value chain i.e. which actor/actors that are most influential in the process of selecting a product that ends up in a construction project.

3.3 Future scenario

This section describes the assessment of the future scenario which consists of three different aspects: a proposed scenario of the future level of BIM, potential moderators that influence the decision point and the decision point of product choice.

Proposed scenario: Highest level of BIM. The proposed future scenario worked as a foundation for assessing the potential future industry dynamic changes. Based on this future scenario, the interviewees were asked questions about how industry dynamics would potentially change and what the moderators for this change might be. The future scenario was derived from literature about future outlooks for BIM and defined as:

> *"BIM-models with high accuracy and level of detail are created, shared and maintained in a collaborative manner throughout all project lifecycle phases. These models incorporate nD information which allows complex analysis and evaluation of the virtual design and construction (Lee et al. 2003). The nD information includes 3D visualization, 4D time visualization and 5D cost information (Eastman 2011). Actors within all lifecycle phases work collaboratively in the same data model (Edgar 2016)."*

Potential moderators. This aspect addressed potential moderators of industry dynamic changes. Specifically, changes in actor-relations and changes in technical ability were in the center of the assessment i.e. does changed relations or higher technical ability affect industry dynamics?

Decision point of product choice. This aspect evaluated if there was any change in the individual actor's perception of where the decision point of product choice was going to be located in comparison to the current situation.

3.4 The assessment framework

Practical usage of the assessment framework followed two sequential steps. Firstly, the current situation was assessed by examining maturity level of BIM and current perception of decision point of product choice. Secondly, the future scenario was assessed by presenting the proposed future BIM scenario and thereafter examining if there would be any change in perception about decision point of product choice and the potential moderators affecting the change. A visual representation of the assessment framework is presented below in figure 3.1.

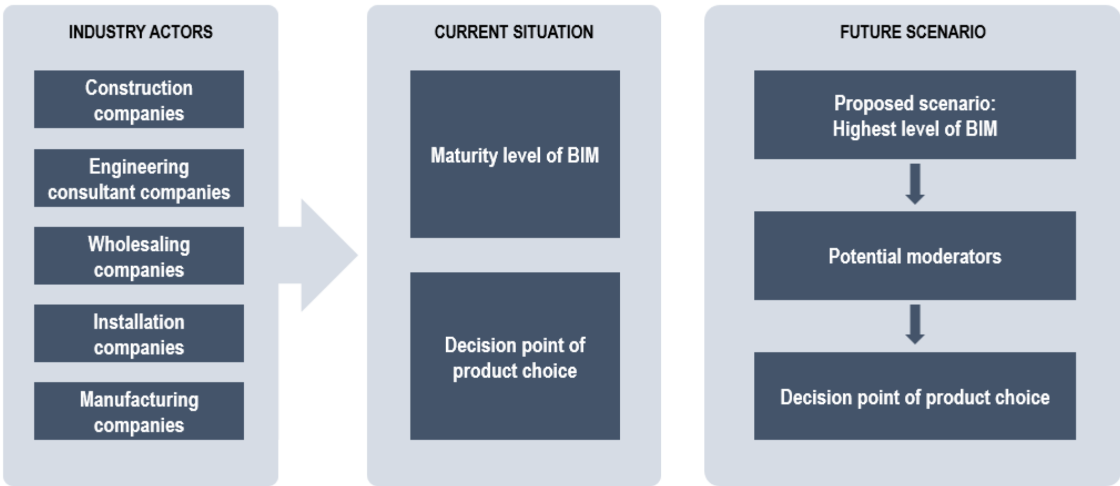

Figure 3.1: Assessment framework

4

Research Methodology

This chapter describes research strategy; research design and process; research methods and research quality criteria, connected to; what is to be researched, how is it going to be researched and why this leads to a certain quality of the study.

4.1 Research Strategy

The research conducted in this thesis has been of an exploratory nature and the research questions were consequently formulated to fit this purpose, using a “what” format. The exploratory approach was chosen in order to assess the BIM phenomena in a new angle and in order to understand the view of industry experts on the development.

There are two contrasting research approaches that describes the relationship between theory and research, called inductive and deductive. The inductive approach has its starting point in data gathering and observations, which is thereafter used to produce theory. The deductive approach has its starting point in the theory from which hypothesis are deduced and thereafter tested by data gathering (Bryman and Bell 2015). The research strategy in this study was mainly inductive since the aim was to assess the BIM phenomena form a new point of view that has not been researched to any significant extent.

In general, the inductive approach is associated with a qualitative research strategy and the deductive approach is associated with a quantitative research strategy. When dealing with fields of research that has an exploratory characteristic, qualitative research strategy is commonly considered appropriate (Easterby-Smith, Thorpe, and Lowe 1991). Qualitative research focuses on words rather than numbers which is used to build up theory and gain new and deeper understanding of a studied topic (Bryman and Bell 2015). For these reasons, the qualitative strategy was considered appropriate in this study.

Bryman and Bell (2015) mention that there are often deductive elements in an inductive research approach and vis-à-vis. This combinatory approach was deemed suitable for this study since it allows the researcher to make use of previous research when developing the assessment framework which is used to build up new theory. Consequently, a deductive approach was partly used but can be considered as a smaller element in the overall inductive approach.

The ontological consideration is constructionism, thus stating that there are no single reality and that realities are constructed in its contexts; different contexts therefore has different realities. The epistemological consideration is chosen to be interpretivism since the belief of no single reality implies interpretation of the reality in its specific context (Bryman and Bell 2015). To shed light on a new research topic, interpretivism is used to explore and get an interpretive understanding of a question form an angle that has not yet been considered. It was therefore not possible to have a positivistic epistemological consideration because there was very limited previously written literature to directly deduce hypothesises from.

4.2 Research Design

The research design is the overall plan of how the researcher will go about answering the research questions in order to fulfill the purpose (Saunders, Lewis, and Thornhill 2016). The purpose of this thesis is to explore expected changes in industry dynamics of potentially fully developed BIM-usage in the construction industry. This particular angle or point of view has not been considered in the present literature and this study was therefore designed to explore this area.

Exploratory research is useful when trying to understand "what is happening; to seek new insights; to ask questions and to assess phenomena in a new light" as described by (Saunders, Lewis, and Thornhill 2009, p.139). Saunders, Lewis, and Thornhill (2016) describes three main ways of conducting exploratory research: search of the literature, interviewing experts in the subject and conducting focus groups. The two first means of conducting exploratory research are used in this study. The purpose and way of using these methods are described in the research methods sub-chapter.

One of the greater advantages with exploratory research is its inherent flexibility, the researcher can change direction when data is gathered and when new insights are gained along the way (Saunders, Lewis, and Thornhill 2016) . The research questions formulation indicate that the whole construction industry needs to be explored in order to get a comprehensive answer. Hence, a broad range of industry actors have to be interviewed and included in the study. The following actors are interviewed: construction companies, engineering consultant companies, installation companies, wholesaling companies and manufacturing companies. An emphasis are put on interviewing the manufacturers since they are the focus of the study, as described in the problem statement and expressed in the subsequent research questions. The majority of the interviews were therefore performed with this actor.

Taking advantage of the flexibility aspect of the exploratory approach, the data gathering process are divided into two phases. Firstly, data are gathered from interviews with construction companies, engineering consultant companies, installation companies and wholesaling companies to get an understanding of their perception connected to how and if the industry dynamics would possibly alter. Secondly, these insights leas to a revision of the interview questions directed to the manufacturing companies to capture interesting details that are brought up in the first phase. This process is referred to as systematic combining and enables the researcher to successively modify the original framework as a result of unanticipated empirical findings (Dubois and Gadde 2002).

The cross-sectional research design described by Bryman and Bell (2015) are determined to guide the process of answering the research questions because it allows the researcher to collect data on a series of topics form several cases, in this study represented by different actors in the supply chain, at one a single point in time. This design also enables the researcher to approach all actors and gather data at the same moment in time and thereafter compare the different findings with each other in a structured way. The data are gathered in a data rectangle which is often used in cross-sectional research described by Bryman and Bell (2015), see figure 4.1.

	Current situation: Most influential actor over product choice	Future scenario: Most influential actor over product choice	Moderators
Construction company A			
Construction company B			
Engineering consultant company A			
Engineering consultant company B			
Installation company A			
Installation company B			
Wholesaling company A			
Wholesaling company B			

Figure 4.1: Cross-sectional data rectangle

4.3 Research process

Based on the research strategy and research design, the research process and activities presented in figure 4.2 are undertaken to answer the research question and fulfill the purpose of the thesis.

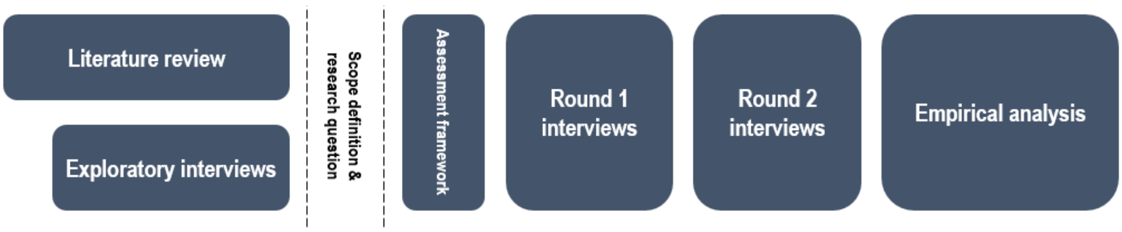

Figure 4.2: Research process activities and sequence

Firstly, informal exploratory interviews and an initial literature review are performed to define the scope and research questions of the study. Three different interview activities are made: telephone interviews, one in-person interview and a visit to a heating, ventilating, air conditioning (HVAC) and plumbing fair in Gothenburg. The targeted respondents of the phone interviews are division managers of technical installation divisions from construction companies and engineering consultant companies. The in-person interview are held with a CEO of a sales organization selling piping systems and components and the HVAC fair interviews are held with people in senior sales positions. Secondly, the initial findings from the first phase are used to define the scope and create an assessment framework that guided the consequent interviews and analysis. The framework is further described in the assessment framework chapter. Thirdly, two rounds of semi-structured interviews are performed and lastly analysis of the empirical data was completed where findings from the literature review supported the analysis.

4.4 Research Methods

4.4.1 Data collection

The following sub-chapter describes the data collection methods used in this study. Data was collected using two methods, reviewing literature and conducting interviews. In this study, 16 one-hour long interviews were performed with five different actors from the construction industry supply chain. In figure 4.3, the companies, position of interviewee and date of interview are anonymously presented.

Company	Position of interviewee	Interview date
Construction company A	Installation Leader	20170523
Construction company B	Category Manager Purchasing	20170523
Engineering consultant company A	CEO Installation Consultants	20170524
Engineering consultant company B	Director Division Buildings: Building Services	20170607
Installation company A	Branch Manager VS	20170531
Installation company B	Department Manager EL	20170608
Wholesaling company A	Senior Purchasing Manager	20170529
Wholesaling company B	Category manager VS	20170524
Piping equipment manufacturer A	Regional Director Northern Europe	20170612
Piping equipment manufacturer B	Sales Trade Manager Sweden	20170613
Piping equipment manufacturer C	Sales Manager VVS	20170613
Piping equipment manufacturer D	Product and Marketing Manager	20170614
Electrical equipment manufacturer A	Sales Manager	20170612
Electrical equipment manufacturer B	Market Manager	20170615
Electrical equipment manufacturer C	Market and Product Development Manager	20170616
Electrical equipment manufacturer D	Sales and Market Manager	20170615

Figure 4.3: Interviewed companies

Literature review

The purpose of the literature review was to get an initial understanding of the topic and to gain insights about industry dominant methods and tools and building information modeling. These insights were then used to set up the research questions, research strategy and research design as well as create the assessment framework.

Bryman and Bell (2015) describes this procedure as a narrative method of literature search and argues that it is suitable for qualitative research with an inductive approach with the above-mentioned purpose to get an initial understanding and narrow down the research scope and questions. The narrative method is less focused in its nature than the systematic approach and therefore covers a broader range of topics (Bryman and Bell 2015) which is suitable for the first part of this study. The literature search is mainly performed using research databases available through Chalmers library's website as well as literature available at the main library at Chalmers Johanneberg campus.

Interviews

Saunders, Lewis, and Thornhill (2016) suggest that interviewing experts in the field is one way of conducting exploratory research. The following chapter describes the interview type, how the interviews are structured and how the interviewees are selected.

Semi-structured interviews. Semi-structured interview are the primary data gathering method used in this study. There are two main reasons why a semi-structured interview approach is appropriate to use in this study. Firstly, the exploratory nature of the research questions implies that a broader answer spectra is desirable and the semi-structured interview allow gathering of information that the researcher did not initially anticipate (Bryman and Bell 2015). Secondly, the partly structured nature of semi-structured interviews with predefined topics and thereby an interview guide, make the analysis process easier since it could be performed in a structured way according to the interview guide. As this study make a comparison between several actor's perspectives, stated as cases in the cross-sectional research design, it is appropriate to have a certain level of structure in order for the researcher to be able to compare these different cases (Bryman and Bell 2015). In other words, semi-structured interviews offer the ability to gather a great span and depth of information and at the same time have a considerably structured format which enables a structured comparison in the analysis, that is desired in this study.

Interview structure. In order to address the research questions, a division into two different stages in time are made, firstly the current situation and secondly a future scenario. Every interview is structured in this way and this approach is used in order to make a clear distinction between the two stages and thereby being able to compare the current situation with a future scenario. The current scenario contain an evaluation of BIM-maturity which is based on previous research performed by Succar (2009) and further described in the assessment framework chapter.

Interview sampling. As described earlier, interviews are performed with construction companies, engineering consultant companies, installation companies, wholesaling companies and manufacturing companies. The interview sampling of manufacturing companies are sampled in one way and the other actors are sampled in a slightly different way. The interview sample of manufacturing companies are done as a mixture between self-selected and convenience sample techniques. Self-selected sampling technique allows the approached individuals to evaluate if they want to be a part of the study or not (Saunders, Lewis, and Thornhill 2016). Convenience sample is a technique used to obtain a sample which is more or less random and can be performed by approaching random people at a shopping mall (Saunders, Lewis, and Thornhill 2016).

As mentioned in the scope & limitation sub-chapter, electrical and piping manufacturing companies are chosen as sub-industries for this study. The researcher attend two different fairs in order to attract potential companies to interview, one for HVAC and plumbing and one for electrical components. The convenience sampling technique are thereby utilized by attending these fairs and then randomly approaching different companies. The self-selected sampling technique are used by starting conversations with company representatives about the research question and objectives. Thereafter, the researcher asks if the company wanted to be a part of the study and in line with the convenience sampling technique, the sampling selection process continued until the previously set sample size had been reached.

The other actors i.e. construction companies, engineering consultant companies, installation companies and wholesaling companies are sampled in a different way. The most well-known actors in each category are written down in a table in Microsoft Excel and thereafter randomized. Thereafter, the researcher starts to call the companies in the randomized order and self-selection sampling technique are utilized in the same way as sampling of manufacturers described above.

Interviews face to face and via telephone. Most of the interviews are performed in a face to face setting, however in some cases the interviews are performed via telephone or skype since these companies' headquarters are located far from the researcher's location. Saunders, Lewis, and Thornhill (2016) express that using an intermediate way of communicating instead of face to face can result in low levels of engagement and trust. The self-selection sampling technique described earlier helps to address these issues because companies and interviewees are selected as a consequence of their interest and engagement in the topic. Even though the researcher is trying to mitigate the risk of low engagement and trust, it is very difficult to judge if the telephone interviews would have had a different quality or outcome if performed face to face.

Interviews recorded but not transcribed. Due to the time constraint of this study, the interviews were not transcribed. The interviews are recorded for the researcher to revisit the interview to complement the notes that are taken by hand on a printed interview guide. Since the gathered data are not transcribed the method of coding can not be used as an analytical method. This method is considered too time consuming for the study but would possibly have contributed to a more unbiased and less interpretative outcome.

4.4.2 Data analysis

Since the research strategy of this study was of a qualitative nature, the analysis also follows in a qualitative manner. The analysis process was done according to the layout of the assessment framework presented in the assessment framework chapter and in line with the overall qualitative analysis processes summarizing and categorizing, presented by Saunders, Lewis, and Thornhill (2016). This systematic way of summarizing and categorizing the data is closely linked to what Yin (2014) describes as a cross-case synthesis. The activities used in this study are: data compilation and synthesis, comparison between current situation and future scenario, conclusion drawing and findings presentation. These are described in more detail below.

Firstly, data is summarized and compiled in the interview guide. The guide is made in Microsoft Excel in order to get a clear overview of the data and to graph the different BIM-maturity scores. The data is first gathered according to each individual interview and each question and divided into one spread sheet representing the current situation and on spread sheet representing the future scenario, in accordance to the assessment framework. Secondly, data from the current situation is compared with data from the future scenario. The differences are analyzed in order to find patterns in the data and to answer the sub-questions to the first research question about the expected industry dynamic changes of potentially fully developed BIM-usage in the construction industry. Lastly, conclusions are drawn from the comparison and consequently the three main research questions will be answered.

4.5 Research quality criteria

Business research is often evaluated according to a variety of quality criteria where the mostly used and prominent are reliability, replicability and validity (Bryman and Bell 2015). There has been a strong association between quantitative research and these quality criteria which has fueled a discussion about the usage of these to evaluate quality of qualitative research and whether it is deemed suitable in this setting (Bryman and Bell 2015).

Lincoln and Guba (1985) developed a set of quality criteria specifically suited for qualitative research. These are used to evaluate the quality of this study. The two main aspects for evaluating quality are trustworthiness and authenticity, but due to the low adoption among researchers of the latter, only the first one will be considered in this study (Bryman and Bell 2015). Trustworthiness consists of four different criteria: credibility, transferability, dependability and confirmability.

Credibility. The credibility criteria is taken into consideration if there is a deviation between how the researcher interprets the interviewees answers and what the interviewee is actually expressing as an answer (Bryman and Bell 2015). This quality criteria is of high importance in this study since the main data gathering method has been interviews. To ensure minor deviation, the researcher has taken the following actions. Firstly, during the interviews clarifying follow-up questions were asked. Secondly, the interviews were recorded and could thereby be revisited to clarify any confusions in the notes taken during the interview. Thirdly, if unclear answers still were found when compiling the data, a follow-up phone call or email was made to the respondent to clarify the issue. Lastly, triangulation is utilized in the study. Several sources of information has been addressed in the study, as recommended by Lincoln and Guba (1985). All the assessment framework's components are based in literature, data has been gathered through interviews with more than one company for each actor and website information and databases has been viewed to confirm companies' efforts in using BIM. The component-databases BIM-Objects and MagiCloud data have been assessed in particular.

Transferability. The transferability criteria refers to the degree of which the findings can be generalized into other social contexts (Bryman and Bell 2015). The majority of qualitative research is meant to study a particular issue in a specific context which implies that the findings of such research tend to be unique in the studied situation (Bryman and Bell 2015). If this criterion is achieved, it is ultimately up to the reader to make generalizations. The qualitative researchers should produce as comprehensive data as possible to enable the reader to make that judgement (Lincoln and Guba 1985).

The researcher has interviewed many actors in the industry to generate a comprehensive understanding of the actor's different reasoning's and standpoints. But even though the data provided in this study can be considered comprehensive and broad enough to be transferable to another context, one should bear in mind that this study focuses on a specific segment of the construction industry and it is therefore very difficult to foresee the outcome of applying the same reasoning in another or a wider context.

Another consideration that should be made is connected to the speed and level of digitalization. The findings are less probable to be transferable since the speed of digitalization is rapid and that different industries already have reached different levels of digitalization. Consequently, in order to generalize the findings from this study factors such as industry structure and speed and level of digitalization should be taken into consideration.

The methodology of this study is considered more transferable than the findings, since it can be seen as a more generic approach to explore a similar question in another context.

Dependability. The dependability criteria is taken into consideration if the researcher keeps thorough records of the whole research process in order for the study to be assessable afterwards (Bryman and Bell 2015). These records could be problem formulations, research participants, recordings of interviews, notes etc. All the data was saved during the process but anonymized due to confidentiality agreements between the researcher and all companies. Records are disclosed but will be anonymized.

Confirmability. The confirmability criteria considers study and researcher objectivity (Bryman and Bell 2015). Since the main data gathering method used in this study was interviews, there was a risk of influencing the respondents. This was mainly mitigated by the formulation of non-leading questions. Moreover, the semi-structured interview format enables having more open questions.

In summary, this study is deemed credible by the researcher, the findings and methodology is transferable with restrictions, the dependability and the objectivity of the study is relatively high.

5
Results & Analysis

This chapter presents the results and analysis of this study. The purpose of this chapter is to firstly answer the sub-questions to the main research question and secondly to provide input to the discussion chapter where the main research question are addressed

5.1 BIM-maturity

The BIM-maturity scores greatly vary between the companies included in this study. These score variations are addressed throughout this first sub-chapter and presented according to the different actors where the manufacturers are addressed more in detail then the other actors. Even though there is a great variation in BIM-maturity between the actors, all the interviewed company representatives express that their companies are interested in acquiring more knowledge about BIM and knowledge about how they can use the technology. Additionally, all the company representatives expect that BIM-usage will increase greatly in the coming years and that BIM will play a central role in designing, planning and executing construction projects in the future. The median score of all actors are presented in figure 5.1.

Company		BIM-Maturity Score	Rounded median score
Construction company	A	29,44	35
	B	40	
Engineering consultant company	A	43,33	41
	B	38,89	
Installation company	A	2,22	8
	B	14,44	
Wholesaling company	A	6,11	9
	B	11,67	
Piping equipment manufacturer	A	27,78	18
	B	1,11	
	C	27,78	
	D	8,33	
Electrical equipment manufacturer	A	0	6
	B	1,11	
	C	11,1	
	D	10	

Figure 5.1: Companies BIM-maturity scores and actors rounded median BIM-maturity score

5.1.1 Construction companies & engineering consultant companies

When comparing the groups of actors, the construction companies and engineering consultant companies have the highest median BIM-score of all interviewed actors. These two actors are consequently the most BIM-mature, compared to the other actors in the supply chain. There are several reasons explaining the generally high level of BIM-matyruty among construction companies and engineering consultant companies.

The most prominent reason is that these actors currently are responsible for the development of BIM-models i.e. they build the BIM-models. In many cases, the construction companies also own the BIM-models and thereby take on the responsibility of populating these with information and data. This is done by gathering information this from other actors such as manufacturers and engineering consultants. Hence, it can be argued that the construction companies already have developed their role into coordinating the development of BIM-models. This is rather natural since construction companies have had this role historically in the construction industry.

More specifically, the measured BIM-maturity scores show that the engineering consultant companies have the highers median BIM-maturity score of all actors. The high score can be derived from the role of the engineering consultant. Put in very simple terms, the role of an engineering consultant is to analyze, design, plan, and research components and structures to accomplish design objectives goals. Calculations, simulations etc. that are carried out to complete these tasks have been performed using software for a long time, even before BIM made was known to the construction industry. Since the engineering consultant role historically has been closely connected to software usage of similar kind to BIM, it is not surprising that these would be one of the first actors to adopt new software and also have a high maturity score.

Another insight that provide evidence for the engineering consultant companies high BIM-maturity score and that the presented future scenario is credible comes from statements made by the interviewees. As an example, engineering consultant A says: We don't think that the future scenario that you present is far away.

In summary, the engineering consultant companies are the most mature actor closely followed by the construction companies. Logically, this seems fairly reasonable with the presented argumentation above.

5.1.2 Manufacturers

The BIM-maturity also vary between the interviewed manufacturing companies. A minority of the interviewed companies have a relatively high BIM-mature while the majority have a relatively low BIM-maturity.

Six out of eight interviewed manufacturing companies have a BIM-Maturity score of eleven or less which indicates that they are generally not very developed within BIM. Interviewees express that it is challenging to understanding how they are going to adopt BIM and how they will be able to create value in the supply chain by using BIM. Most of the companies are in initial planning stages and are now starting to develop their initial BIM-strategies.

The text is divided into comparison of three different groups in order to identify patters in the BIM-maturity scores. Firstly, the two groups of manufacturers, piping equipment manufacturers and electrical equipment manufacturers, are compared. Secondly, the companies within each of these group of manufacturers are compared. Lastly, groups consisting of companies with similar BIM-maturity scores are compared.

Starting with comparing the two groups of manufacturing companies. The piping equipment manufacturers have a higher median score than the electric equipment manufacturers. The piping equipment manufacturers included in this study generally produce more complex and differentiated products than the electrical equipment manufacturers. Products with a very low differentiation level are generally not necessary to specify by brand, which can be one explaining factor for why manufacturers of these products show a low BIM-maturity. Another general difference between the two groups is that the products produced by the piping equipment manufacturers in general get specified earlier in construction projects while products produced by the electrical equipment manufacturers gets specified at a later point in time. This might influence how early these different manufacturing actors have adopted BIM because there has been a greater push on products that are specified earlier.

In order to understand the variation within each manufacturing actor group, a comparison between the individual companies has been done. An interesting insight are gained when comparing BIM-maturity score of the different companies in relation to their revenue. The comparison reveals that piping equipment manufacturers with higher revenue have higher BIM-maturity score, see figure 5.2. In other words, companies with higher revenue seem to be more BIM-mature. Since BIM is relatively new to the manufacturers and because working with BIM is initially associated with high investment costs, it is rather normal that the larger companies are leading the development because they have the size to fully utilize complex technologies and the financial power to adapt the latest technologies first. The smaller companies usually take on a "following" role where they observe which technologies that are worth investing money into because they cannot afford to adapt non-successful technologies. However, this does not seem to be the case for the electrical equipment manufacturers, see figure 5.2. Company revenue might be one factor affecting BIM-maturity but there are obviously more influencing factors, one of these seem to be connected to which products that the companies manufacture. The two piping equipment manufacturers with highest BIM-maturity scores, piping equipment manufacturer A and C, produce products that are typically installed in places with very little available space. It is therefore often challenging to fit these products and they need to be installed in a planned and optimized way. An explanation to why these specific companies have the highest BIM-maturity scores can be that BIM is typically useful in these more complex installation situations.

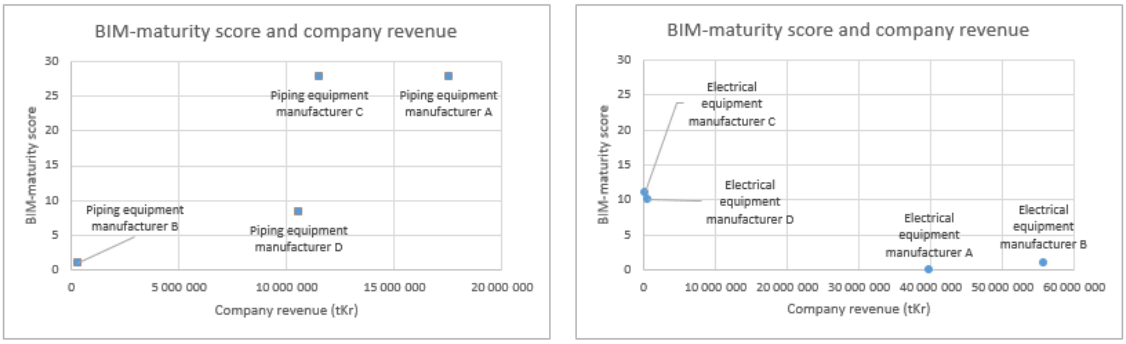

Figure 5.2: Scatter-chart BIM-maturity score and company revenue

Examining product categories within the electric equipment manufacturers included in the study show that companies producing more complex and differentiable products are more BIM-mature. Electrical equipment manufacturer C and D, with BIM-maturity scores of eleven and ten respectively, produce more complex and differentiable products compared to electric equipment manufacturer A and B, with BIM-maturity scores of zero and one respectively, who in comparison produce relatively simple and generic products. The most mature company, electrical equipment manufacturer C, produce products which has design features and are visually identifiable when installed in a building i.e. people can see the product when it is installed. BIM are used to visualize how products will appear when they are installed and it can therefore be very useful to use BIM-objects for products that are visual and have design features. This reasoning can explain why electrical equipment manufacturer C have the highest BIM-maturity score of all electrical equipment manufacturers.

Examining all manufacturing companies by dividing these into groups consisting of companies with similar BIM-maturity disclose interesting insights. The companies were divided into the groups high, middle and low BIM-maturity scores.

The most mature companies are piping manufacturer A and C, with a BIM-maturity score of 28. As described before, these companies manufacture products that are typically installed in places with little available space which motivate BIM usage and can explain why these companies are most BIM-mature. The products are often also installed in systems where several products are connected to each other which also advocate usage of BIM, mainly because of the visual and analysis aspects. Additionally, their considerably large company size in terms of revenue has probably also influenced early BIM investments compared to piping manufacturer B that manufacture similar products.

The manufactures with a middle maturity level: piping equipment manufacturer D, electrical manufacturer C and D have a couple of characteristics in common. The products that these companies produce are generally not installed in tight spaces, compared to the manufacturers in the high maturity group, which could explain the lower BIM maturity with the same reasoning as before. These products are often also installed in systems as described before which motivates BIM usage and can explain that the BIM-maturity are considerably higher than zero.

Lastly, inspecting the group with lowest BIM-maturity shows that electrical equipment manufacturer A and B produce very standardized and generic products that are usually not specified by brand in the design phase. Moreover, these products are not installed in a system of products. Both of these aspects could be explanations for the companies low BIM-maturity score. The third company included in this group, piping manufacturer B, does not fit the product description of the first two companies. The product characteristics are more similar to the companies in the group with highest BIM-maturity whether the company characteristics are not very similar. Piping equipment manufacturer B are a considerably smaller company compared to the companies in the high maturity group and the company are also privately owned in comparison with the other companies who are publicly owned. Additionally, piping equipment manufacturer B has recently shifted focus from products suited for mainly smaller villas to products for commercial buildings. All these factors have probably influenced the BIM-maturity and explain why it is very low at this point in time.

In summary, there are a great variety in BIM-maturity among the manufacturers as mentioned in the beginning of this sub-chapter. These variations could be explained by the following aspects: product characteristics, system attributes, installation situation and company size.

5.1.3 Installers & Wholesalers

According to the empirical findings, the installation and wholesaling companies have a relatively low BIM-maturity. This is not too surprising, since these companies do not directly work with developing BIM-models or BIM-components. The interviewed installation companies use BIM in a very limited way as of today. They do not create or modify any objects in the model, instead they only view the models in order to plan their installations and prevent collisions between different components and systems. The interviewed wholesaling companies are not involved in any aspect of the BIM models today and they are unsure about how they will utilize BIM and which role they will have connected to BIM in the future. The wholesaling companies have a marginally higher median BIM-maturity score than the installation companies. This is rather surprising since it seems like the installation companies work more with BIM than the wholesaling companies. There are also a great spread of BIM-maturity scores between the individual companies which could be an indication that the BIM-development are in its initial stages regarding these actors and has not yet stabilized. The variation could also be explained by the low amount of actors included in the study.

5.1.4 Research question 1.1 answer

What are the current status of BIM-maturity for all actors in the construction industry? Construction companies and engineering consultant companies are most BIM-mature. They have BIM operations and strategies in place and a fairly clear vision about future development and outlooks. BIM-maturity among manufacturing companies varies a lot depending mainly on product characteristics, system attributes, installation situation and company size. Most of the manufacturing companies are in the early stage of BIM development and have not yet established a strategic implementation plan. Even though all companies express interest and attach great value to BIM, the majority of the wholesalers, installers and manufactures do not know how they will use BIM in their specific roles in the supply chain and what kind of knowledge they need to acquire. All BIM-Maturity scores are presented in figure 5.1 above.

5.2 Decision point of product choice

The answers regarding the decision point of product choice are very different between the interviewed companies. Different companies have different opinions about both where the decision point are located in the current situation and where it could potentially be located in the future scenario. Additionally, the interviewed companies express that there are at least two factors that influence the variations in what these believe that the decision point are located - project delivery method and product characteristics.

Three distinct opinions about how the decision-making power moves within the supply chain have been identified among the interview answers: upward shift, downward shift and no shift. The directions of the shifts are defined in line with the supply chain from the product perspective presented in figure 5.3.

Figure 5.3: Installation industry supply chain from a product perspective

These shifts are further nuanced into different types of shifts. These are denoted cases further in the text as defined in figure 5.4. A synthesis of the interview answers connected to the potential decision point of product choice, shifts and cases can be found in figure 5.5. The following text will present the different possible cases.

Cases	
Upwad shift	Move from installers upward the supply chain
Upward shift	Move from high to higher point in the supply chain
Downward shift	Move from higher to lower point in the supply chain
No shift	Decision point located high up in the supply chain
No shift	Spread of decision point in supply chain
Shifts	
↓	No shift in decision point
→	Upward shift in decision point
←	Downward shift in decision point

Figure 5.4: Definition of cases and shifts of the decision point of product choice

Company		Current situation: Decision point of product choice	Future scenario: Decision point of product choice	Shift
Construction company	A	• Installation company	• Construction company • Owner/Buyer	→
	B	• Construction company	• Construction company	↓
Engineering consultant company	A	• Construction company	• Construction company	↓
	B	• Construction company • Engineering consultant company	• Construction company • Engineering consultant company	↓
Installation company	A	• Owner/Buyer • Installation company	• Owner/Buyer • Installation company	↓
	B	• Installation company • Owner/Buyer	• Installation company	←
Wholesaling company	A	• Owner/Buyer	• Owner/Buyer	↓
	B	• Owner/Buyer • Engineering consultant company	• Owner/Buyer • Engineering consultant company	↓
Piping equipment manufacturer	A	• Installation company • Engineering consultant company	• Owner/Buyer • Engineering consultant company	→
	B	• Owner/Buyer • Construction company • Installation company	• Construction company	→
	C	• Installation company • Construction company	• Construction company	→
	D	• Owner/Buyer • Installation company	• Owner/Buyer • Installation company	↓
Electrical equipment manufacturer	A	• Installation company	• Engineering consultant company	→
	B	• Owner/Buyer • Construction company • Installation company	• Engineering consultant company	→
	C	• Wholesaling company • Installation company	• Owner/Buyer • Engineering consultant company	→
	D	• Owner/Buyer • Engineering consultant company • Construction company	• Owner/Buyer	→

Figure 5.5: Synthesis of the interview answers connected to decision point of product choice, shifts and cases

Upward shift: A move from installers upward the supply chain. There were in total seven interviewed companies that believed in a shift of decision point where the installation companies would get a reduced decision power over product choice. Six of these actors were manufacturers and one was a construction company. In general, these companies predict that a shift from installation companies upwards in the supply chain towards construction companies, engineering consultants and buyers/owners would be possible in the future scenario with full BIM-usage. In other words, product decisions could be made higher up in the supply chain in the future scenario, shifting from the installers who widely make the decisions currently..

> *The buyer/owner will most probably be able to direct the decisions in another way than today. They make some decisions today but has to engage a consultant in a lot of cases. BIM will enable the buyer/owner to make more decisions because of the visualization possibilities that come with the technology and because of a higher level of information transparency in the industry.* ***- Piping equipment manufacturer A***

> *The actor that owns the BIM-model will probably have the greatest influence over product choice. Logically, this would be the contractor as it seems today because this actor serves as a connector between different actors involved in a construction project.* ***- Piping equipment manufacturer B***

> *We see that the decision-making shift upwards in the supply chain, from installers towards contractors, especially when it comes to standardized and simple products. The reason being that planning of a construction project with BIM most often is initiated by the contractor and that they thereby own the model.* ***- Piping equipment manufacturer C***

> *Engineering consultants and architects will most probably be able to make more specific data-driven decisions because of the availability of information and will therefore have a greater influence on product decisions in the future scenario.* ***- Electrical equipment manufacturer A***

Upward shift: A move from a high to higher point in the supply chain. There was only one company, electric equipment manufacturer D, that believes in a shift in decision point from a high position in the supply chain to an even higher position. The owner/buyers would be able to make more products decisions in the future scenario but these decision would still be made with help from the engineering consultant companies and construction companies.

> *The owner/buyer can become more involved in the process of choosing products because of the visualization aspect of working in a digital BIM environment. The decision point could consequently shift upwards in the supply chain.* ***- Electrical equipment manufacturer D***

Downward shift: A move from higher to lower point in the supply chain. One of the interviewed installation companies predicts that the decision point would potentially shift from a higher to a lower position in the supply chain. They believe that installation companies will make more decisions about products in the future scenario if they develop BIM-capabilities in-house.

> *We as installers get more influence when products/material is chosen and motivate a specific choice. BIM will enable us to easier visualize the effects of choosing a specific product especially when it comes to impact on lifecycle costs. But it depends if we develop this ability in-house or if the technical consultants become the actor how works with this.**- Installation company B***

No shift: Decision point located high up in the supply chain. The majority of the interviewed companies in the actor groups construction companies, engineering consultants and wholesaling companies do not believe that BIM will affect where in the supply chain product decisions are made. They believe that the decision point is placed somewhere upwards in the supply chain around construction companies, engineering consultants and buyer/owners in the current situation and that this will remain even in the future scenario.

> *Contractors would potentially still make the final decision in the future scenario. These decisions would be based on information from installers and manufactures and the decisions will probably be based on more and better information which would lead to product/material choice that is more sustainable, cost efficient and environmentally friendly.**- Construction company B***

> *There will probably be no change in which actor that is the most influential in the product/material decision process. The construction company will still gather information about price and thereafter choose to alternate the product choice and convince the owner/buyer that the other product/material perform the same function.**- Engineering consultant A***

> *There will probably not be any noteworthy change or shift in influential power within the supply chain because of wide industry adoption and usage of BIM.**- Engineering consultant B***

> *The buyer/owner is still the most influential actor in the process of choosing products/material to a construction project.**- Wholesaling company A***

> *More complex products will still be influenced to the largest extent by technical consultants but less complex product/material decisions could possibly be made by the buyer/owner because of the increases in technical ability that BIM brings.**- Wholesaling company B***

No shift: Spread of decision point in supply chain. There are two interviewed companies that express that the decision point would possibly not change in the future scenario. The decision point would potentially still be spread in the supply chain and decisions will be made by the installation companies and the owners/buyers, according to these interviewed companies. Piping equipment manufacturer D also expresses that the spread has to do with which project delivery method that is utilized.

> *Cannot imagine that BIM will shift the decision point or affect different actors influence in the decision-making process. The owner/buyer will still specify which function they want to achieve and we [the installation companies] will still have the same high influence that we have had before.**- Installation company A***

> *In general it is important to try to affect the buyer/owner on a long-term perspective and installer on a short-term perspective these are the most influential actors in the current situation and will probably also be in the future scenario. It also depends on the project delivery method; the installer has great influence in DB projects and the buyer/owner is most influential in DBB projects.**- Piping equipment manufacturer D***

5.2.1 Research question 1.2 answer

What are the expected effects on decision point of product choice between the industry actors? Three general answers to the research question have been identified among the synthesized interview data above. Firstly, eight out of 16 interviewed companies believe in an upward shift of the decision point. Secondly, seven out of the 16 interviewed companies believe in no shift of the decision point. Lastly, only one interviewed company believe in a downward shift of the decision point.

More importantly, 13 out of 16 companies believe that product decision will be made by actors high up in the supply chain i.e. construction companies, engineering consultant companies and owners/buyers. Only one interviewed piping equipment manufacturer and the two interviewed installation companies believe that installation companies will make decisions about products in the future scenario with industry-wide BIM usage.

5.3 Moderators

There is a disagreement among the interviewees regarding the moderating factors for a potential shift of decision point. The main understanding among all interviewed actors is that aspects connected to BIM are enabling a shift. But there are also relatively many interviewees that consider other aspects disconnected from BIM as more important. These moderators will be further explained below.

5.3.1 Moderators connected to BIM

The moderators connected to BIM are identified as increased technical ability, information transparency and BIM-model ownership.

Wholesalers and manufacturers consider an increased technical ability that BIM offers and information transparency as the most important factors moderating a shift in decision point within the supply chain. This is mainly because actors higher up in the supply chain i.e construction companies, engineering consultant companies and owners/buyers are able to make more data-driven product decisions earlier in the design phase because they have a larger amount of information available at this point in time with BIM and can visualize the effects of choosing a specific product better. The data-driven decisions with more and better information lowers the risk of making decisions about products and ensures that the chosen products will work in the specific context. This enables construction companies, engineering consultants and owners/buyers to write more detailed specification and move away from specification formulations as “a product or similar” and move more towards specifying specific products from specific manufacturers.

> *We could be a part of the early design phase with the buyer/owner and the engineering consultants by providing them with key data, if our knowledge within BIM increases.* ***- Wholesaling company A***
>
> *The increase in technical ability that BIM brings will enable the buyer/owner to make more decisions without involving the engineering consultants since more information is gathered in the models and it is thereby easier to get a comprehensive understanding of different systems and products.* ***- Wholesaling company B***
>
> *BIM will increase the technical ability for the majority of actors involved and information transparency will probably also increase as a consequence. The buyer/owner will more easily get a comprehensive overview of their projects and thereby being able to make more specific decisions.* ***- Piping equipment manufacturer A***
>
> *An increase in technical ability will make it possible to specify more products with a higher degree of certainty early in the design phase.* ***- Piping equipment manufacturer B***
>
> *The technical ability of BIM would potentially increase re-usage of concepts that has been used in previous projects.* ***- Piping equipment manufacturer D***
>
> *Technical ability will most probably increase with BIM and provide visualization possibilities, a better cost control and a more transparent information flow in the supply chain. Engineering consultants and architects will be able to make more decisions and will possibly take a leading role in coordinating construction projects.* ***- Electrical equipment manufacturer A***
>
> *The increase in technical ability allows visualization and will help the engineering consultant and buyer/owner to make decision.* ***- Electrical equipment manufacturer B***
>
> *Higher technical ability will enable buyer/owner, engineering consultant and architect to make precise decision early in the design phase. The most important factor is the visualization aspect.* ***- Electrical equip-***

ment manufacturer C

*Technical ability increase with visualization abilities will increase the ability for buyer/owners to make decisions.**- Electrical equipment manufacturer D***

Another moderating factor that is important to consider is which actor owns the BIM model. Many actors believe that the actor who claims ownership of the BIM model will be the actor who has the largest decision power over choosing products.

*The actor that own the BIM-model will probably have the greatest influence over product choice. Logically, this would be the contractors as it seems today because this actor serves as a connector between different actors involved in a construction project.**- Piping equipment manufacturer B***

We see that the decision-making shift upwards in the supply chain, from installers towards contractors, especially when it comes to standardized and simple products. The reason being that planning of a construction project with BIM most often is initiated by the contractor and that they thereby own the model. ***- Piping equipment manufacturer C***

5.3.2 Moderators disconnected from BIM

The moderators that are disconnected from BIM are identified as project delivery methods and ineffective pricing within the construction industry.

The construction companies and engineering consultants generally consider project delivery method as the most important moderator for a shift in decision point of product choice. They argue that the project delivery method governs which actor in the supply chain that make the decision about product selection. In design-build projects, it is usually the construction company that chose products and in design-bid-build projects, it is usually the engineering consultant that makes the decision. These actors believe that this will still be the case in the future scenario where BIM is widely adopted and used in the construction industry.

Even though this might be the case, both construction companies and engineering consultants experience an increase in usage of collaborative project delivery methods in larger construction projects. These collaborative project delivery methods are usually run by a collaborative team consisting of owner/buyer, primary designer and primary contractor but can also include sub-designers and sub-contractors. They think that this will affect the decision point in a way that more actor's opinions will be taken into account when decisions are made and consequently spread out the decision power over more actors compared to other more traditional project delivery methods. However, it is ultimately up to the owner/buyer to decide which project delivery method they want to use but the interviewed representatives from the construction companies and engineering consultant companies express the collaborative methods have increased in popularity over the last years.

> *BIM drives a change in delivery methods from traditional to collaborative practices. Decisions about products and materials would therefore be made jointly with more actors and information involved. We could see that these actors would be the construction company, the owner/buyer and the installation company.**- Construction company B***
>
> *What we see is that there is more collaboration between contractor, engineering consultant and buyer/owner in the initial phases of construction projects today. The buyer/owner decides which project delivery method they want to use and the collaborative methods that we have been involved in up until this point has been satisfying.– **Engineering consultant company A***
>
> *The influence will still depend on the project delivery method. There will probably not be any noteworthy change or shift in influential power within the supply chain because of wide industry adoption and usage of BIM.– **Engineering consultant B***

BIM is also closely connected to these collaborative methods and actors mention that these two are fueling each other. It can therefore be argued that BIM indirectly effects the choice of project delivery method which in turn could influence the decision point of product choice.

> *From our point of view, BIM is meant to be used with collaborative project delivery methods and these are fueling each other in adoption.– **Wholesaling company A***

The second identified moderator that is disconnected from BIM is the ineffective pricing within the construction industry. Today's construction industry has very low price transparency where bonuses and kick-backs are commonly used between wholesalers and installers. The high building costs are a consequence of the low price transparency within the industry and is a strong driving force and moderator that can shift decision power in the supply chain.

> *An upward decision point shift is driven by the industry's ineffective pricing model. There is a major lack in transparency regarding prices in the supply chain today because of bonuses, discounts and kick-backs between actors. **- Piping equipment manufacturer C***
>
> *There is a problematic situation in today's construction industry where installers and wholesalers have relations built on kick-backs and annual discounts. The invoices that the installers show the construction companies are not always correct because of this culture.– **Construction company A***

5.3.3 Research question 1.3 answer

What are the potential moderators for a shift in decision point? Five different moderators have been identified from the interview answers these was divided into moderators connected to and disconnected from BIM. The moderators connected to BIM are identified as increased technical ability, information transparency and BIM-model ownership. The moderators that are disconnected from BIM are identified as project delivery methods and ineffective pricing within the construction industry.

6 Discussion

This chapter discuss the results and presents potential industry dynamic changes and applicability of the findings in other industries.

6.1 Discussion of results

This sub-chapter presents a discussion of the results presented in the previous chapter.

6.1.1 BIM-maturity

The BIM-maturity among the industry actors are similar to the expected distribution, taking previous literature into consideration. In particular in line with Hardin and McCool 2015 who states that the architects, engineers and construction companies are the most mature. The literature tend to focus on these actors i.e. architects, engineers and construction companies (Hardin and McCool 2015; Eastman 2011; Succar, Sher, and Williams 2012). This thesis on the other hand puts these actors into the context of some other actors (i.e. installation companies, wholesaling companies and manufacturing companies) that make up the construction industry and shows where these are located on the BIM-maturity scale. An interesting outcome of this thesis is that these other actors are not very BIM-mature in comparison to the engineering consultants and construction companies. Even though their BIM-maturity scores are relatively low, the interviewees expressed that BIM are highly prioritized on their agenda and that they want to develop their BIM-capabilities. But even if the interviewees express that they want to develop their BIM-capabilities, top-management need to assess the business case and see if investments in BIM are going to be profitable. Today, the case might not look too attractive because full utilization of BIM's advantages are only realized when many companies are using the technology. In the near future the situation might be different. However, with this reasoning it is reasonable to believe that there could be some inherent insecurity in the interview answers regarding future ambitions of BIM-capability development. Nevertheless, the general perception among the interviewed actors is that usage of BIM has been increasing in the Swedish construction industry in the last years which support BIM investments. Similarities can be found with the development pattern of BIM adoption in the American construction industry presented by Hardin and McCool 2015.

Even if the usage of BIM in the Swedish construction industry is increasing, it does not necessarily translate into a wide adoption of BIM throughout the whole supply chain. The results of BIM-maturity score from this study provides evidence that wholesaling companies, installation companies and manufacturing companies lag behind the construction companies and the engineering consultants when it comes to BIM-maturity. But this is in fact not too surprising since construction companies and engineering consultants are ultimately responsible for the design and construction of buildings which are closely connected and heavily supported by information technology systems such as BIM. For these actors the business case of implementing BIM into their operations has therefore provided more benefit than effort much faster than for the other actors.

The benefits of working with BIM and the level of effort has not yet been clear for the wholesaling companies, installation companies and manufacturing companies. The benefits and level of efforts are probably getting increasingly clear for these actors as construction companies and engineering consultants are starting to demand BIM-compatible products and processes from their suppliers.

6.1.2 Decision point of product choice

The result shows that there is no coherent understanding, among the interviewed actors, of where the decision point is located today or where it will be in the future. The finding that there are a wide range of opinions, are rather surprising. It could nevertheless be an effect of the fragmented industry structure, where all the different actors have been operating within their own silos with a lack of communication, information exchange and collaboration over the actors' borders (Hampson, Kraatz, and Sanchez 2014). Historically the transparency has been so low that no one have had a good overview of the whole supply chain of actors (Hampson, Kraatz, and Sanchez 2014), which could possibly be a reason for the non-coherent answers from this study.

However, the majority of all interviewed actors believe that decisions about products will be made higher up in the supply chain in the future. But there is however disagreement about whether this is due to a shift in decision point or if the decision point already is located higher up in the supply chain. As mentioned before, eight out of 16 companies believe that higher maturity of BIM will shift the decision point of product choice upward in the supply chain and seven out of 16 companies believe that the decision point are already located high up in the supply chain. The only actor with a different opinion, who believe that higher BIM maturity will shift the decision point downward the supply chain, are the installation companies. There are reasons to believe that the interview answers from this actor are somewhat biased since the scenario where more product decisions are made higher up in the supply chain and with better price transparency, are not a favorable situation for the installation companies. The reason why is because a major large part of their current business depend on adding a profit margin to the products and materials that they buy and use in their installations (Johansson 2013).

It would also be reasonable to believe that the actors with higher BIM-maturity score are able to anticipate the future industry development with a higher accuracy than actors with lower BIM-maturity score because they are more knowledgeable within the field. The actors with high BIM-maturity scores have a gathered opinion that the decision point will shift upward or that the decision point already is located high up in the supply chain. This reasoning will be used as input for further argumentation in the discussion chapter about industry dynamic changes.

6.1.3 Moderators

The results from this study regarding an increase in technical ability with BIM are in line with the literature about information management (Kensek and Noble 2014), visualization (Granroth 2011; Eastman 2011) and evaluation (Granroth 2011; Eastman 2011). But a part form what the literature study expose, this study shows that industry experts believe that the increased technical ability will enable construction companies, engineering consultant companies and owners/buyers to make more decisions about products than before. Information availability and transparency will reduce the risks involved in making decisions about product early on in construction projects.

The manufacturers and wholesalers, who have relatively low BIM-maturity scores on average, believe in a decision point shift due to increase in technical ability. Although technical ability might enable a shift, there could be other moderating factors such as project delivery methods that are more important to consider. The low BIM-maturity or their role in the supply chain can restrict the manufacturers to see the more important factors influencing the decision point in the supply chain.

Even if BIM works as an enabler, project delivery methods will probably also govern where the decision point of product choice are going to be located in the future. Actors with the highest BIM-maturity score, construction companies and engineering consultant companies, consider project delivery method as the most important moderator for the decision point of product choice position in the supply chain. The interviewed industry experts and scholars believe that BIM is fueling the development and usage of collaborative project delivery methods and strategic alliances within the construction industry (Eastman 2011; AIA 2007; Succar, Sher, and Williams 2012; Grilo and Jardim-Goncalves 2010; Isikdag and Underwood 2010). Using collaborative project delivery methods and strategic alliances would hypothetically increase the amount of decisions that could be made earlier in construction projects but these decisions would involve more actors and the decision power would therefore be spread out over more actors than when using more traditional project delivery methods (Wilhelm 2007).

Whether or not strategic alliances form, or collaborative project delivery methods increase in usage, BIM-model ownership will be an important factor determining decision power over choosing products in construction projects according to some of the interviewed industry experts. Logically, the owner of the digital model would have high decision power over which products that are added into the model. This factor was not expected to be important initially by the researcher but when comparing with other industries such as the manufacturing industry, digital ownership is starting to get attention and has been rising up as an increasingly important topic to consider when industries go through digital transformations (Kautzsch, Krenz, and Sitte 2016).

Moderators connected to and disconnected from BIM are intertwined and can be looked upon from different points of view. Increasing technical ability and information transparency could potentially enable a decision point shift but a shift is probably still going to governed by the chosen project delivery method. Increased usage of BIM might fuel collaborative project delivery methods and thereby shift decision point. It can be concluded that is a complicated situation with many dependencies and a lot of potential outcomes.

6.2 Discussion of industry dynamic changes

Most interviewed companies think that more decisions will be made higher up in the supply chain in the future compared to the current situation. The majority also believe that it is a higher maturity of BIM within the construction industry that could, directly or indirectly, shift the decision point of product choice upwards the supply chain. This lead to the hypothesis: Higher maturity of BIM shifts the decision point of product choice upward the supply chain. The following sub-chapters are based on this hypothesis and discuss what this could possibly imply for some actors in the construction industry.

Installation companies changed role. The installation companies might have a changed role in the future construction industry supply chain. Installation companies have historically had a major decision power over choosing products in construction projects (Schober and Hoff 2016). This has been the case because decisions about products have not been made early in the design phase by construction companies and engineering consultants but rather defined as a function at that stage (Eastman 2011; PCUK 2014; Ashworth 2016). Because of the hypothetical shift of decision point, the installers could get an altered role in the supply chain, going from being an actor that both choose products and install them, to being an actor who only carry out the actual installations. This would not be a particularly favorable situation for the installation companies since a great part of their profits comes from the margins that they add on to purchased installation products today (Johansson 2013).

Changed sourcing behavior affecting wholesaling companies. A shift of decision point of product choice upward the supply chain could also cause changed sourcing behavior among construction companies which in turn could affect the wholesaling companies. An effect of that companies higher up in the supply chain would be able to make more product decisions is that the products could be sourced earlier and directly from manufacturers without interference of installations companies as described above. If construction companies, for instance, would increase their direct sourcing from manufacturers, the wholesalers' role could potentially transform. Today wholesaling companies works as a link between manufacturing companies and buyers and they are thereby also working as an important marketing channel for manufacturing companies (Kerin and Hartley 2017). It could be argued that the wholesaling companies have a relatively high decision power over choosing products to construction projects today. As more decisions are being made by actors higher up in the supply chain, the wholesaling companies power and importance in the construction industry supply chain could decrease and their role could potentially transform into only being a logistic partner. However, a hindering factor for cutting out the wholesaling company is that manufacturers to a large extent depend on wholesalers for contact with installation companies and construction companies as mentioned before. There are often company policies stating that all sales should go through wholesalers since these provide storage-keeping services and have a large contact network (Kerin and Hartley 2017). Larger manufacturers would probably have a better possibility to set the wholesaling company aside because they are more often equipped with an in-house sales team and have the necessary capabilities in place to handle the situation better than smaller manufacturers.

Higher price transparency could break the kick-back culture between wholesalers and installers. The Swedish construction industry has a widespread lack of price transparency on products and materials. Wholesalers provide discounts to installers which can span from 30-90%, but these prices are usually not declared when products are sold upwards in the supply chain (SOU 2012). The hypothetical scenario where more product decisions are made higher up in the supply chain could potentially shatter the kick-back culture between wholesalers and installers because price information are included in BIM-objects and models. Connecting price with functionality at an earlier phase could also hinder that products get exchanged at a later phase in construction projects, making it increasingly important for manufacturers to be specified in the initial blueprints.

New actors providing BIM-objects online are emerging. In recent years, new actors have been emerging as a consequence of the increasing adoption of BIM in the construction industry. These actors provide BIM object to architects, designers and specifiers that are available through online cloud databases. Having a structured and consolidated BIM object database vastly improves the productivity of the architects, designers and specifiers work because they do not need to develop the BIM objects themselves or contact each specific manufacturer in order to get BIM objects or the information they need. Instead, they can download the BIM objects from the cloud and import these into their design software. Examples of websites providing downloadable BIM objects today are: BIMObjects.com (bimobjects.com), National BIM Library (nationalbimlibrary.com) and MagiCloud (magicloud.com).

6.3 Applicability of findings other industries

Several findings of this thesis are applicable when analyzing digital transformations in other industries. Obviously, different industries have distinct transformation processes when digitalizing. Pace and magnitude of the evolving shift in the supply chain of a distinct industry indeed differ dependent on the nature of the specific industry. However, industries that goes through digital transformations usually go through a similar cycle of technological adoption and experience shifting roles within the supply chain (Olleros and Zhegu 2016). The findings of this thesis allow for a generalization both regarding the empirical findings as well as the methodological assessment of digital transformation in general.

Starting with the generalization of the empirical findings. Firstly, this thesis finds that digitalization of the construction industry certainly could shift the traditional roles in the supply chain and also leads to new actors entering the industry. An example of this is the new actors who provide BIM object databases online. This phenomenon occurs not only in the construction industry. In general, the individual company that operates as a certain actor in the supply chain (e.g. manufacturers) needs to monitor the trends and changes continuously in order to observe new industry entrants and determining its emerging role in the supply chain. An ongoing digital transformation usually causes turmoil and uncertainty but could at the same time present opportunities for companies. Individual companies could take on new, more favorable, position in the supply chain or expand their current position.

Secondly, the interviewed companies in this thesis are very interested in adopting new technologies and digitally transform but they do not have the knowledge to do so. In general, this is a very common problem that a lot of companies are facing in times of digitalization (Olleros and Zhegu 2016). Companies could address this problem by taking in external knowledge, utilizing industry knowledge platforms or form strategic alliances.

Thirdly, the empirical finding reveals that there is a mutual dependence of companies digitalizing in the supply chain. Specifically, in the digitalization of the construction industry this means that it is difficult for the industry to fully take advantage the BIM technology if all actors do not use it. E.g. construction companies can on the one hand be very mature within BIM and provide perfect BIM models where everything is accounted for but if the sub-contractors on the other hand have a low BIM maturity, they may not be able to access the models and work according to the plans. In general, the mutual dependence of digital maturity, where more mature actors cannot fully utilize a new technology because of less mature actors, are most probably an issue for other industries going through similar transformations. Consequently, it could take a long time for all actors within an industry to reach the same maturity level, which is necessary to utilize the full potential of the digitalization.

6.3.1 Methodological assessment

As mentioned earlier, the findings of this thesis also allow for a generalization regarding the methodological assessment of digital transformation. The assessment framework that was developed for this thesis worked as a tool for structuring the logic on how to assess an industry that goes through a digital transformation and find out what the expected industry dynamic changes it would pose. The same framework could be used to obtain a structured logic when investigating how digitalization are affecting industry dynamics in other industries. The general steps of the framework are generally applicable to other industries going through a similar transformation because it clearly structures the logical reasoning behind the assessment. The framework is firstly used to define the industry actors, secondly it assesses the current situation within the specific industry and thirdly based on the two previous steps explores the future scenario.

Considering an example from the past when computer aided design was introduced into the “engineering industry”. As mentioned in the literature review, digitalization of the engineering industry and the introduction of computer aided design changed the industry where draftsmen, designers and engineer’s roles merged (Weisberg 2009). The assessment framework that was developed for this thesis would have been useful in the study digitalization in the “engineering industry” in retrospect. The framework could have been used to firstly define the industry actors that would be affected by the digitalization e.g. designer companies/department, product development companies/departments and calculation engineering companies/department. Secondly int would be used to assess the current situation in order to gain an understanding of the current industry and the different actors position in the supply chain. Lastly, based on the two previous steps the future scenario would be explored to reveal potential industry dynamic changes that could occur in the future i.e. companies, department and roles of engineers merging.

A future example where the framework could be used is the ongoing development of internet of things (IoT) technologies in the production industry. The framework could be used to make an assessment on how digitalization of the production industry and specifically integration of IoT would affect the industry dynamics such as shifting roles, changed power positions between actors, emergence of new operational methods, adjusted actors’ responsibilities and emergence of new actors with new roles. Conclusively, almost every industry is going through some sort of digital transformation in the near future and the framework that was developed for this thesis could be used as a tool to investigate and understand future challenges and opportunities that the companies are facing.

7
Conclusion

This chapter presents the conclusions of this thesis and put these in relation to the initial purpose and research questions.

The purpose of this thesis was to explore the expected industry dynamic changes of potentially fully developed BIM-usage in the construction industry. Three research questions were formulated to guide the research and the findings were then used to discuss potential industry dynamic changes.

Firstly, it was found out that BIM-maturity vary among the industry actors where the construction companies and engineering consultant companies were the most mature and the manufacturing companies, wholesaling companies and installation companies are in the early stage of BIM development and have a lower BIM-maturity. However, all actors attached great value to BIM and expressed eagerness to acquire knowledge within the field. They also indicated that the industry as a whole are moving towards a higher BIM-maturity.

Secondly, full utilizations of BIM might shift the decision point of product choice from installers to actors higher up in the supply chain namely construction companies, engineering consultant companies and owners/buyers. 81% of the interviewed companies believed that product decisions will be made by actors high up in the supply chain in the future.

Lastly, identified moderators for a shift of decision point were both connected to and disconnected from BIM. Moderators connected to BIM were identified as increased technical ability, information transparency and BIM-model ownership. The moderators that were disconnected from BIM was identified as project delivery methods and ineffective pricing within the construction industry.

In conclusion, the industry is moving towards a higher BIM-maturity where more decisions will possibly be made higher up in the supply chain in the future and a higher maturity of BIM within the construction industry could, directly or indirectly, shift the decision point of product choice upwards the supply chain. These findings lead to the hypothesis that a higher maturity of BIM shifts the decision point of product choice upward the supply chain. Based on this hypothesis, the following industry dynamic changes are to expect in the future.

- Installation companies could get a changed role in the supply chain, going from being an actor that both choose products and install them, to becoming an actor who only carry out the actual installations
- Changed sourcing behavior among construction companies could affect the wholesaling companies' role. Their decision power and importance in the construction industry supply chain could decrease and their role could potentially transform into only being a logistic partner
- A shift in decision power where more product decisions are made higher up in the supply chain could potentially shatter the kick-back culture between wholesalers and installers because price information are included in BIM-objects and models
- New actors who provide BIM object through online cloud databases have been emerging because of the increased adoption of BIM in the construction industry. These actors will probably play an important role in the future digitalized construction industry and possibly take over parts of the decision power that the wholesaling companies loose in the transition

All actors within the construction industry will surely be affected of the ongoing digitalization and the industry dynamic changes that follows pose both opportunities and challenges for the actors. It is therefore important that companies are monitoring how the development evolves and adapt in adequate ways to continuously provide value in the supply chain and to stay competitive in the future marketplace.

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A
Appendix 1

The BIM maturity framework that was used in the interviews are presented in this appendix. The framework have four pages: A.1, A.2, A.3 and A.4.

BIM-UTVÄRDERING							
		0	1	2	3	4	5
TEKNOLOGI	Hur välutvecklad är eran programvara för att arbeta med BIM?	• Vi använder inte i dagsläget någon form av programvara för att arbeta med BIM	• Används huvudsakligen till att skapa 2D ritningar • Det finns inget definierat sätt att använda, lagra eller utbyta information inom organisationen • Datautbyte mellan olika programvaror är inte möjligt	• Används för att skapa 2D och 3D leverabler • Det finns ett väldefinierat sätt att använda, lagra och utbyta data inom organisationen • Datautbyte mellan olika programvaror är möjligt	• Digitala modeller används för att genomföra kvantifieringar, specifikationer och analytiska utvärderingar • Dataanvändning, lagring och utbyte är övervakat och kontrollerat av någon. • Det är någons uppgift att se till att datautbyte mellan olika programvaror är möjligt	• Digitala modeller är synkroniserade så att olika projektgrupper kan arbeta med samma modell • Den övergripande organisationsstrategin statuerar att datautbyte mellan olika programvaror måste vara möjligt.	• Digitala modeller är ständigt uppdaterade/optimerade för att möta nya mjukvarukrav och förväntningar • Alla ärenden relaterade till interoperabel dataanvändning, användning och utbyte är dokumenterat, kontrollerat och reflekterat kring för att se förbättringar
	Hur välutvecklade är era hårdvaruinvesteringar?	• Vi har ingen hårdvara som kan hantera programvara för att arbeta med BIM	• Vi har hårdvara som kan hantera BIM-programvara men den är otillräcklig för utnyttja full funktionalitet.	• Vi har hårdvara som kan hantera BIM-programvara inom hela organisationen	• Det finns en strategi för att dokumentera, hantera och underhålla hårdvara som är nödvändig för att hantera BIM. • Investeringar i hårdvara är riktad mot att öka produktiviteten i arbetet med BIM	• Investering i hårdvara är väl integrerad i den finansiella planer, företagsstrategi och prestationsmål.	• Exciterande hårdvara är kontinuerligt testad and uppgraderad efter identifierade behov. • Hårdvara för att hantera BIM är en del av organisationens eller projektets konkurrensfördel
	Hur välutvecklat är erat nätverk för att dela data?	• VI har inget nätverk för att dela data	• Individer, organisationer och projektteam använder alla verktyg som finns tillgängliga (mail, USB-stickor osv.) för att kommunicera och dela data.	• Nätverkslösningar för delning av data finns inom och mellan organisationer men är inte gemensamma för alla aktörer.	• Nätverkslösningar för delning av data finns inom och mellan organisationer hanteras väl via gemensamma plattformar (ex. intranät eller externt)	• Nätverkslösningar gör att flera aspekter av BIM-processen kan integreras genom oavbruten realtidsdelning av data, information och kunskap. • Lösningar inkluderar projektspecifika nätverk/portaler som möjliggör dataintensivt utbyte (interoperabel utbyte) mellan intressenter.	• Nätverkslösningar utvärderas kontinuerligt och ersätts av de senaste testade innovationerna. • Nätverk underlättar kunskapsanskaffning, lagring och delning mellan alla intressenter. Optimering av integrerade data-, process- och kommunikationskanaler är rigorös.
SIDA 1							

Figure A.1: BIM-assessment page 1

BIM-UTVÄRDERING							
		0	1	2	3	4	5
PROCESS	Hur hanteras kunskap av BIM inom organisationen?	• VI har ingen kunskap om BIM	• BIM-kunskap delas vanligen informellt mellan personal (genom tips, tekniker och lärdomar).	• Delad kunskap samlas, dokumenteras och överförs således från informell till explicit.	• Dokumenterad kunskap lagras på ett lämplig sätt	• Kunskap är integrerad i organisationssystem; Lagrad kunskap görs lättillgänglig för medarbetare.	• Ansvarig för kunskaps anskaffning, presentation och spridning finns
	Hur hanteras informationsinnehåll och detaljnivå i BIM-modellerna?	• Vi hanterar inte BIM-modeller	• 3D-modeller (en BIM-produkt) lider av för höga, för låga eller inkonsekventa detaljnivåer	• Det finns riktlinjer för hur modellerna ska utformas (ex. informationsinnehåll och detaljnivå)	• Branschstandardiserade (Model Progression Specifications, BIPS, "informationsnivåer" eller liknande) riktlinjer för hur modellerna ska utformas (ex. informationsinnehåll och detaljnivå) används	• Modellerna definieras enligt "Model Progression Specifications"	• Modellerna utvärderas ständigt; feedback-loopar främjar kontinuerlig förbättring.
	Hur enhetlig är organisationens BIM-vision och hur hög är förståelsen inom organisationen?	• Vi har ingen vision för BIM	• Chefer har olika visioner för BIM. BIM implementering genomförs utan en vägledande strategi.	• Chefer har en gemensam vision om BIM. BIM-genomförandestrategin saknar dock handlingsbara detaljer.	• Visionen att genomföra BIM kommuniceras och förstås av de flesta personal. BIM-genomförandestrategin är kopplad till detaljerade handlingsplaner och en övervakningsenhet.	• Visionen delas av personal över hela organisationen och/eller projektpartnerna. BIM-genomförandet, dess krav och process/produktinnovation är integrerade i organisatoriska, strategiska, ledande och kommunikativa kanaler.	• Intressenter har internaliserat BIM-visionen och uppnår den aktivt. BIM-genomförandestrategin och dess effekter på organisationsmodeller utvecklas kontinuerligt och justeras med andra strategier. Om förändringar behövs, implementeras de proaktivt.
POLICY	Hur hanteras utbildning av BIM inom organisationen?	• VI har ingen BIM-personal att utbilda	• Mycket lite eller ingen utbildning tillgänglig för BIM-personal	• Utbildningskrav finns definierade och ges typiskt endast vid behov	• Utbildningskrav följer fördefinierade breda kompetens- och prestationsmål	• Utbildningen är integrerad i organisationsstrategier och prestationsmål	• Utbildningen utvärderas och förbättras kontinuerligt
	Hur är riktlinjerna för arbete med BIM utformade?	• Vi arbetar inte med BIM	• Det finns inga BIM-riktlinjer, dokumentationsprotokoll eller modelleringsstandarder	• Grundläggande BIM-riktlinjer finns tillgängliga (ex: träningsmanual och BIM leveransstandarder)	• Detaljerade BIM-riktlinjer finns tillgängliga (träning, standarder, arbetsflöde, undantag ...)	• BIM-riktlinjerna är integrerade i övergripande policyer och affärsstrategier	• BIM-riktlinjerna är kontinuerligt och proaktivt raffinerade för att återspegla lärdomar och branschens bästa praxis
SIDA 2							

Figure A.2: BIM-assessment page 2

BIM-UTVÄRDERING								
			0	1	2	3	4	5
BIMUTVECKLING	NIVÅ 1	Hur utvecklad är hantering och framtagning av BIM-objekt inom organisationen?	• Vi har ingen programvara för att skapa och/eller hantera BIM-objekt	• Vi håller på att implementera programvara för att skapa och/eller hantera BIM-objekt • Inga process- eller policyändringar identifierade för att följa denna implementering	• Pilotprojekt för BIM-objekt är i slutfasen • BIM-process- och policykrav identifieras. Implementeringsstrategi och detaljerade planer utarbetas.	• BIM-processer och policys initieras, standardiseras och kontrolleras.	• BIM-teknologier, processer och policyer integreras i organisationsstrategier och anpassas till affärsmål	• BIM-teknologier processer och policyer granskas kontinuerligt för att dra nytta av innovation och uppnå högre prestationsmål
	NIVÅ 2	Hur ser eran samarbetsförmåga internt/externt kring BIM-modeller ut?	• VI har inget samarbete kring BIM-modellerna, varken internt eller externt	• Vi har ett oplanerat samarbete i BIM-modellerna; Internt samarbetsmöjligheter som är ostrukturerade inom och mellan projekt	• Samarbete i BIM-modellerna sker internt kring en uppgift i taget	• Samarbete i BIM-modellerna sker internt kring flera uppgifter samtidigt	• Samarbete i BIM-modellerna kring flera uppgifter samtidigt som inkluderar nedströms spelare	• Samarbete i BIM-modellerna kring flera uppgifter samtidigt som inkluderar alla nyckelaktörer
	NIVÅ 3	Hur ser utbytet mellan organisationer ut av nD-modeller över projektets livscykelfaser?	• Integrerade modeller genereras inte	• Integrerade modeller genereras av en fåtal projektintressenter	• Integrerade modeller genereras av en stor delmängd av projektintressenter	• Integrerade modeller (eller delar av) genereras och hanteras av de flesta projektintressenter	• Integrerade modeller genereras och hanteras av alla viktiga projektintressenter	• Integration av modeller och arbetsflöden ses över kontinuerligt och optimeras. Integrerade modeller bidrar till många intressenter längs byggnadskedjan
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Figure A.3: BIM-assessment page 3

BIM-UTVÄRDERING

			0	1	2	3	4	5
ORGANISATION	ORG.	Hur hanteras ledarskap och roller kopplat till BIM?	• BIM ledarskap och roller finns inte ens informellt inom organisationen	• BIM ledarskap är obefintlig; Genomförandet beror på enstaka tekniskt kunniga och drivna personer inom organisationen	• BIM ledarskap är formaliserat; Olika roller inom implementeringsprocessen är definierade.	• Fördefinierade BIM-roller kompletterar varandra för att hantera implementeringsprocessen	• BIM roller är integrerade i organisationens ledaskapsstrukturer	• BIM-ledarskapet muterar kontinuerligt för att möjliggöra ny teknik, processer och leveranser.
	PROJEKT	Till vilken grad drivs BIM-projekt interorganisationellt?	• Vi har inga BIM-projekt	• Varje projekt drivs självständigt. Det finns ingen överenskommelse mellan berörda parter att samarbeta utöver deras nuvarande gemensamma projekt.	• Intressenter ser bortom enskilda projekt. Samarbetsprotokoll mellan projektintressenter definieras och dokumenteras.	• Samarbete mellan flera organisationer över flera projekt hanteras genom tillfälliga allianser mellan intressenter.	• Samarbetsprojekt genomförs av interdisciplinära organisationer eller interdisciplinära projektgrupper. En allians av många viktiga intressenter.	• Samarbetsprojekt genomförs av självoptimerande interdisciplinära projektgrupper som omfattar de flesta intressenter.
	MARKNAD	Till vilken grad finns BIM-komponenter (virtuella produkter och material som representerar fysiska) tillgängliga inom branschen?	• Det finns inga leverantörsgenererade BIM-komponenter tillgängliga	• Mycket få leverantörsgenererade BIM-komponenter. De flesta komponenterna är utarbetade av programutvecklare och slutanvändare.	• Leverantörsgenererade BIM komponenter är alltmer tillgängliga eftersom tillverkare / leverantörer identifierar affärsfördelarna.	• BIM-komponenter är tillgängliga mycket tillgängliga/sökbara via centrala arkiv • Komponenter är inte interaktivt kopplade till leverantörernas databaser	• Tillgång till BIM-komponenter är integrerade i BIM-programvaran. Komponenter är interaktivt kopplade till källdatabaser (för pris, tillgänglighet mm.)	• Dynamisk flervägsgenerering och utbyte av BIM-komponenter mellan alla projektintressenter via centrala eller nätverksdatabaser

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Figure A.4: BIM-assessment page 4