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BIM Implementation in the Production Phase of the Construction Process

Site Management Teams' Knowledge, Attitude and Needs

Master's thesis in the master's program Design and Construction Project Management

EFPRAXIA BRANTITSA
RAKEL NORBERG

Department of Architecture and Civil Engineering
CHALMERS UNIVERSITY OF TECHNOLOGY
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Technical report no ACEX30-18-72
Department of Architecture and Civil Engineering
Division of Construction Management
Chalmers University of Technology
SE-412 96 Göteborg
Sweden
Telephone + 46 (0)31-772 1000

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ABSTRACT

Building Information Modelling (BIM) is a digital database of all the characteristics of a construction, containing all the necessary data and information stakeholders can use for decision making throughout the life-cycle of a project. However, the use of BIM is mainly limited to the design phase of a project in the construction industry. Therefore, this thesis is focused on how BIM is brought out on the production sites in a studied company by looking into what the site management teams' knowledge, attitude and needs from BIM. For this reason, there will be a research using interviews and questionnaires on finding which knowledge and attitude the site management teams of the studied company have about BIM and what is needed in order to improve the implementation of BIM in the production phase of a project. The findings from the thesis showed that the site management teams know of different uses of BIM, but they do not know how they can use it. Within the studied company there are systems in place and information, but in the studied region this have not been communicated to the site management teams. There is a lack of education among the teams and they experience very little support from the company. The issues lie in a lack of time to learn the software and no real support function existing in the organization. However, in other regions of the company they have support functions for BIM implementation and therefore it is possible to learn from within the organization. The thesis' conclusion sees that the studied region of the organization needs to develop a strategy, education and support system for BIM implementation in the production phase. A further study could look into how different support functions operate and what is deemed functioning.

Keywords: BIM implementation, BIM, site management teams, attitude, knowledge, needs, BIM on site

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LIST OF ABBREVIATIONS

BAC	-	Business Area Construction
BAH	-	Business Area Housing
BIM	-	Building Information Modelling
CAD	-	Computer Aided Design
IFC	-	Industry Foundation Classes - general file format
CC	-	Construction Company

ENGLISH – SWEDISH DICTIONARY

Construction document	-	Bygghandling
Construction engineer	-	Byggingenjör
Planning engineer	-	Entreprenadingenjör
Site manager	-	Platschef
Supervisor	-	Arbetsledare
System document	-	Systemhandling
Turnkey contract	-	Totalentreprenad
Work preparation	-	Arbetsberedning
Work Site Outline	-	Arbetsplatsdispositionsplan

PREFACE

The thesis could not have been written without the aid from many people. We would therefore like to extend our thanks to the people that somehow has been involved with the making of it.

- Mikael Johansson, our supervisor at Chalmers for the help with our questions.
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- Max Bergström, for letting us write the thesis at the studied company and aiding with both the questionnaire and the information about the company's different ways of working with BIM.
- Our student opponents, for their input to improve the report.
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Rakel Norberg

1 INTRODUCTION

Building Information Modelling, known as BIM, is a digital and virtual model of a building which contains accurate data regarding the geometry, design, spatial relationships, geography, quantities and properties of building elements, material inventories, cost and time estimation of the project. Using this model, the life-cycle of the building is visible. BIM can be used for 3D illustration of buildings, for code reviews of building projects by different offices such as fire departments, cost estimation, material orders, construction process and delivery schedules of the materials used, for finding errors and reducing conflicts and collisions of pipes, walls, beams etc. and for facility management (Azhar, 2011).

The first appearance of the term "Building Information Model" was by professor Chuck Eastman of the Georgia Institute of Technology in 1975, and in the beginning of 1980s the term started to be used in the United States and Europe, referring basically to the design of the object and not to the process (Popov, 2016). In the United Kingdom, research and development became regarding CAD tools and software, such as the creation of Really Universal Computer Aided Production System (RUCAPS), which continued to other countries later as well (i.e. AutoCAD in Hungary) (Adamou, 2014). In addition, after 2D-CAD drawings were introduced 3D-drawings, 3D-models and information databases appeared, which formed the base for the creation of BIM (Olsson and Arvidsson, 2012). The American architect Phil Bernstein was the first who used the term "Building Information Modelling" which, later, was spread out by Jerry Laiserin, who referred to this methodology as *"a means of representing the manufacturing process and as a means of facilitating exchange and interoperability of project information in digital form"* (Goniakakis, 2014). Although the term BIM appeared decades ago, just recently it started to be implemented, focusing, however, more in the design phase of a project rather than in the production phase. (Olsson and Arvidsson, 2012).

This thesis examines how the BIM-model is implemented at the production site in different building projects within a large Swedish construction company, what is included in the implementation, and how the BIM properties are used. This was done by conducting a questionnaire sent out to the site management teams in one region at the studied company as well as interviewing some people with different background and positions from these teams. The focus of the research is on what knowledge and attitude the site management teams have about BIM and what they need in order to implement BIM in the production phase of a project. In the design stage a BIM model is made and then used for calculations, coordination checks, quality checks, quantifying, and sometimes scheduling. When a project moves into the production stage the model is handed over to the site team that decides what they want to do with it. Most teams do not use the model at all, instead they rely on traditional 2D-printed drawings, mainly because there is lack of knowledge on how to implement BIM and a lack of a support system.

1.1 Aim and Outcome

The aim of the thesis is to investigate the attitudes and knowledge of BIM of the site management teams within the studied construction company, if and how they use BIM and what they need to implement or continue implementing BIM within production.

The outcome of the thesis is supposed to give the studied organization a base to work on for future implementation of BIM. It will give them knowledge on what they need to improve and communicate to their employees in the production phase of construction.

1.2 Research Questions

The thesis will focus on and answer the following questions:

- What knowledge do the site management teams have about BIM?
- What are their attitudes towards BIM?
- What is needed to help site management teams to implement BIM in production phase?

1.3 Scope and Limitations

The thesis investigates the site management teams in the construction and housing divisions in one region at the studied organization. A review of the relevant literature is required. Through the literature, there will be a clear idea and understanding of the theoretical background regarding BIM, its purposes and outcomes, it can be found what other authors have written and thought about BIM and which the future research or questions are on this subject (Bryman and Bell, 2011). Articles, books, previous theses and the company's documents are mainly used for the literature background.

The focus of the thesis lies within the production only in one region at the studied company and therefore the use of BIM in the other phases of construction will only briefly be mentioned, but not investigated. The necessary research data will be collected through questionnaires which will be sent to the site management teams as well as through interviewing some of these teams' members. The focus of both the interviews and the questionnaire is on what the site management teams need to implement BIM in the production, their knowledge of BIM and to investigate the attitudes towards BIM among the them. The thesis will also not investigate different software used during production, instead it focuses on how access and ease of use is for the professionals on site.

1.4 Structure of the Thesis

The thesis report structure follows as presented below:

- Chapter 2 contains a review of the literature regarding the opportunities and challenges of BIM, BIM implementation, how BIM is used on site and which BIM software's there are. How the studied construction company uses BIM is also pointed out.
- Chapter 3 introduces the methodology used in order to collect and analyse the necessary data.
- Chapter 4 contains the presentation and analysis of the results.
- Chapter 5 covers a discussion regarding how the results of the research are connected to the literature about BIM.
- Chapter 6 contains the conclusions of the research done. The thesis finishes with the answering of the research questions and some suggestions on how BIM implementation in the studied company can be improved as well as future studies are referred.

The work structure of the thesis is visualized in figure 1.

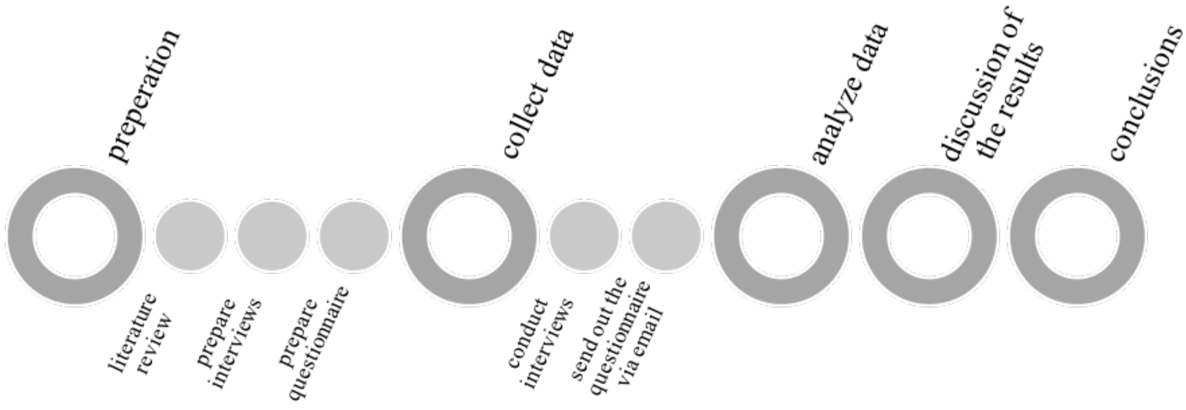

Figure 1: Structure of the thesis work

2 THEORETICAL BACKGROUND

This chapter includes a review of the literature concerning BIM and its implementation at the production sites within the construction industry. The BIM-model will be referred to both as BIM-model and as model in the thesis.

2.1 Definition of BIM

There are several definitions of Building Information Modelling. Adamou (2014) points out that one of the definition BIM is a kind of software, a second one refers to BIM as a 3D representation of a building and a last definition as just a collection of building information, organized in a database, easily manageable, visual and numeric. Goniakakis (2014) believes that BIM is a combination of all the definitions above and even more.

A complete definition of BIM is that BIM is the digital database of all physical and functional characteristics of a construction, which is the source of data and information common to all stakeholders and able to support reliable decision-making throughout the lifecycle of a construction project and its phases, from pre-design to demolition phase (Adamou, 2014). It is a methodology for analysing, optimal planning, management and the documentation of the construction of the building and its installations. Essentially, it manages the information (i.e. all the data contained in the designing of a building, such as the number of windows, the cost of materials, the electromechanical equipment etc) at all phases of the project life. It is an integrated process, based on coordinated and reliable information about a project (Goniakakis, 2014). In the thesis BIM is defined as a digital database of all the characteristics of a building, physical as well as functional.

2.1.1 Level of Development

The input of information in a 3D-model is what differs a BIM-model from 3D-CAD. The model can be used in several different ways with more information put in. When adding information to the model it is important to know what it is supposed to be used for since different end-users have different demands on information. Therefore, before creating the information database, the model owner should identify the end-user, since it is unnecessary to add more information than needed (Weygant, 2011). Weygant (2011, p. 127-134) identified seven types of information that could be used in the model:

- Dimensional information
- Identification information
- Performance information
- Installation/application information
- Sustainability/usage information
- Management and maintenance information
- Specification information

To make this simpler different levels of development (LOD) has been identified that both controls the geometrical detail level and the level of information contained in the model. The information is usually linked to a specific construction component (i.e. wall, window, pipe, etc), specifying its characteristics and materials. It is also important to note that the level of detail needed for a visualisation is different for the one needed for calculations. A visualisation model needs to have high detail levels on the surface areas, but for a calculation-based model the level of information needs to be higher to give correct calculations.

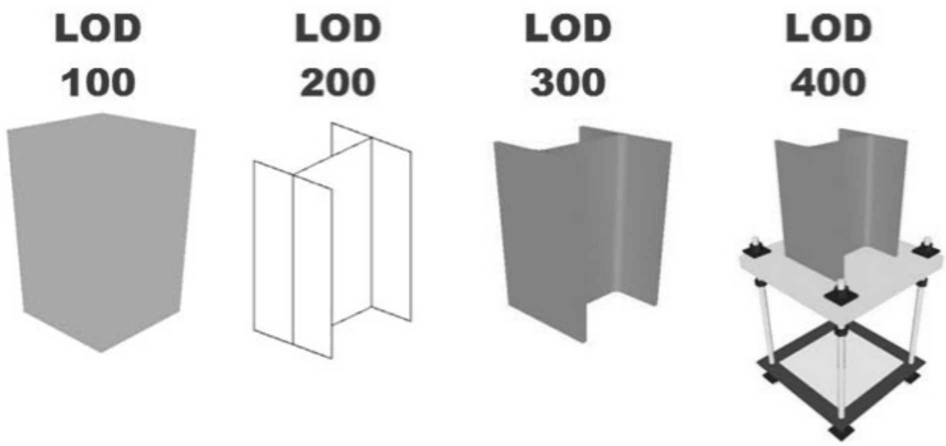

Figure 2: Levels of development (adopted from Buidling Design + Construction, 2018)

The American Institute of Architects (2008) presented the five levels of development for a BIM model. The idea with different levels of development is to make it possible to control the amount of information contained within a model at the same time as controlling the detail level (Weygant, 2011). The levels are explained in further detail in table 1, but Bedrick (2008) explained the five levels briefly as follows:

- 100: Conceptual
- 200: Approximate geometry
- 300: Precise geometry
- 400: Fabrication
- 500: As-built

Level of development, LOD	
100	A mass analysis of the model were the basic form and room volumes are represented. No more information is contained within the model. The model can be used for general calculations based on areas (Weygant, 2011). Interior walls are not modelled. Estimations are made from square meter area (Bedrick, 2008).
200	The model elements are added as generalized systems with very approximate volumes. Openings are present, but not necessarily specified as windows or doors. Cost estimations can be made on area, volumes and quantities. (Weygant, 2011). Generic, placeholder interior wall with general thickness. Some properties can be included (Bedrick, 2008).
300	The elements are accurate in volumes, shape and location. The exact materials are not necessarily specified but the detail level is added. The component has information on performance levels and construction requirements. It is possible to make specific cost estimations based on the model (Weygant, 2011). A specific wall type is modelled. Properties such as cost, U-value and other can be specified (Bedrick, 2008).
400	The elements are specified, material selection is put down and the amount of information increases. All the information should be there to make an accurate cost estimation based on the components (Weygant, 2011). The wall as specified fabrication details (Bedrick, 2008).
500	Fully accurate digital representation of the components is made. Not applicable in common models and should be reserved for use when high-resolution renderings are needed or close-up views (Weygant, 2011). The wall is modelled as it is going to be in reality (Bedrick, 2008).

Table 1: Level of development

2.1.2 BIM Software

There are different kind of BIM tools that construction companies could use in different phases of their projects. The software in architectural design which the studied company mainly uses are Solibri Model Checker, Revit, Tekla BIMsight, SketchUp and BIM 360. Solibri Model Checker is a BIM tool which is used to check the design of the building using parametric constraints and to find possible errors, conflicts or wrong codes. It facilitates the workflow of the design and it is an excellent visualization tool of the model. However, the relations between the building components may not always be correct, it works only with metric units and completely new constraints cannot be created (Building Informatics of Aalborg University, 2018). In addition, Revit is a BIM software which is most appropriate for visualization, coordination and documenting the sizes and location of the various structures of a building. It develops new custom parametric objects and customizes the predefined objects (NEED4B, 2018). Moreover, Tekla BIMsight is used by construction companies for construction project collaboration. Using Tekla BIMsight, the project teams can check for clashes and share the information using the same BIM environment (Trimble Solutions, 2018). Furthermore, SketchUp is used for programming, diagramming, design development, detailing, documentation. It includes page layout tools and 2D vector tool (LayOut), surface in different styles, uploading the model on Google Earth and 3D Warehouse and supports other programs as well (SketchUp, 2018). Finally, BIM 360 is a software which is used in construction to improve the construction project delivery. It improves the quality control, manages issues, creates daily reports of the construction work and it contributes to the right workflow of the different phases of a project (Autodesk, 2018). According to Lindblad (2013), BIM software are not easy in use and does not satisfy the users' needs completely.

It is common that different consultants work with different software. To ensure compatibility everyone should work with Industrial Foundation Class (IFC) models. With IFC all the sub-models can be connected into a single model no matter the original software used to create the sub-model (Dainty, A. et al, 2015).

2.2 Opportunities and Challenges of BIM

The use of BIM in the construction industry has both advantages and disadvantages. Based on Azhar (2011), there are a lot of advantages for a project and organization to use BIM. One of the benefits of using BIM is the more effective processes. This means that all the information needed for a project can be easily shared and re-used making the processes faster. BIM allows documents and plans to be prepared at the same time as the design of the project (Lan et.al., 2015). In addition, the design of the project might become better using BIM since it is analysed more, there are more details, simulations are performed quicker, and all stakeholders can be easily informed due to visualization of the project (Azhar, 2011). Also, there is a common database model for a project team which reduces the errors when the team exchange information, something that does not happen with the use of 2D-models (Lan et.al., 2015).

Moreover, there could be better controls of the project life cycle costs and the environmental impact of the project. The cost estimation of it could be more accurate and the time needed to find the cost estimation and the project time may be reduced (Azhar, 2011). According to Lindblad (2013), the quality of work will be improved as there will be an increase of productivity, reduction of risks, better communication and participation of project teams. This will lead to a reduction of costs and an improvement of profitability and relationships. What is also important is the use of BIM models by contractors in order to visualize the construction of the building and identify any challenges and errors (Lan et.al., 2015).

However, some of the disadvantages and problems of using BIM may be firstly the disagreements about copyright issues of BIM and the lack of legislation about it (Azhar, 2011). It is not clear who is the owner of BIM data and how the process works when the client pays for using BIM, but the construction company uses interior information in the project. When performing a BIM implementation within a company the legal standpoint quickly comes into consideration. How the responsibility of the BIM data is divided, a potential risk for everyone involved (Azhar, 2008; Miner, 2006). The roles of a project team and their responsibilities about databases and loading are complicated and not clear enough and there is a lack of a legal framework about implementation of BIM and the participation of owner to the design and construction of project (Eastman et al., 2011). Traditionally in European countries the architect has the responsibility to do lists with the materials (Epstein, E, 2012), something that might change depending on the contract formulation when working with BIM. In Swedish law the descriptions of drawings have the highest legal accuracy. This means that if there is a conflict between the description and the drawing, the description is deemed as the legal requirement. Eynon (2016) says that the legal issues are not a big problem since it in reality just comes down to that every discipline retains their responsibility and ownership over the parts that they design. However, according to Malmkvist (2018), it might still be necessary to introduce a standard contract to help the parties to handle the legal aspects of the model and responsibilities. In the future the issues might decrease since the information will move entirely from drawings, into a BIM-model.

Another problem of BIM is that there are no instructions about how to use and implement it. Enshassi et.al. (2011) also mention some problems of using BIM. They point out the lack of knowledge which both owners and project team may have, something that may cost a lot and increase the time scheduling of the project if the information the team uses is not obligatory and the data is too detailed. It is difficult to change the way people are used to work and insert new processes and software as they prefer to do it as “they have always done it” (Olsson and Arvidsson, 2012). What actually make the implementation difficult is the lack of training and personal motivation of employees (Eastman et al., 2011). Some more issues they point out are that implementation of BIM seems to be really expensive and there is not effective collaboration between the stakeholders of a project about using BIM.

Another disadvantage of BIM is that the input, update and review of BIM data take time which in turn increases the cost of the project. Although there will be positive effects in efficiency and time scheduling of the project and BIM seems to be profitable throughout the lifecycle of a project, the cost of BIM use will still exist and responsibility for accuracy, cost and time scheduling remains fluid and should be encountered legally (i.e. use of contracts) (Azhar, 2011).

Moreover, there is no specific standards and a common platform to use when implement BIM, making construction companies to use their own way and “agendas” regarding BIM standards. Some BIM technologies are compatible only with other technologies from the same software developer as well. Also, BIM is mainly used throughout the design phase of a project and its implementation ceases in the next stages of construction (Olsson and Arvidsson, 2012). The software use might be seen as an issue as well since working with different software can give rise to compatibility issues (Chen, C. et al. 2017).

Opportunities	Challenges
More effective processes	Disagreements about copyright and licensing issues and lack of legislation and contracts about BIM
Preparation of plans at the same time as the design phase	Not clear who is responsible in case of risks appearance
Better design of the project	Input, update and review of BIM data take time
More details	Lack of instructions on how to use BIM
Quicker simulations	Lack of knowledge, training and personal motivation
Visualization	Increase of cost and time if there is not right implementation
Common database	Risk of using unnecessary information
Reduce of errors	Risk of using too detailed data
Better control of costs and environmental impacts	Use of different software
Reduce of cost and time	Expensive implementation
Better communication and participation	No specific standards and a common platform
Increase on the return on the investment	Use mainly in the design phase

Table 2: Opportunities and challenges of BIM

2.3 BIM Implementation

Implementing BIM within a company is similar to implementing other changes. According to Erika Epstein (2012): "*Implementing BIM requires commitment, planning, testing, and time to develop best practices and integrate the process.*" When taking the decision to implement BIM it is important to create a plan for implementation (Epstein, E, 2012). Ahmad et al (2012) identified several different implementation plans for BIM in the literature: "Top-down; bottom-up; slow and drawn out; using a selected team; using multiple teams; and implementing on a specific projects, all projects or the entire organization." (Ahmad et al, 2012). When implementing BIM in companies Chan (2014) research identified twelve main barriers; they are:

- Lack of qualified in-house staff to carry out the BIM related works
- Lack of training/education
- Lack of standards
- Lack of client demand

- Lack of government's lead/direction
- Lack of incentive to have subcontractors and suppliers (lower part of the supply chain) to adopt BIM
- High cost
- Uncertainties over interoperability of BIM software with other software
- Lack of IT infrastructure
- Uncertainties over ownership of data and responsibilities
- Lack of new and/or amended forms of construction contracts
- Current professional indemnity and insurance terms

Further the same research found some support systems that was wished from the professionals to get to full BIM implementation. They were:

- Providing guidance on use of BIM
- Defining levels of BIM working for reference in professional services agreements
- Providing training
- Developing data exchange standards
- Developing new forms of contract

These results show that to succeed with a BIM implementation companies have to invest in both cost and time. The highest issues for the personnel was reflected in the support systems that they wanted (Chan, 2014). This is controlled by the senior management levels. According to a study by Chen et al (2017) BIM acceptance was not a problem in the lower levels of the organization, but at the senior management levels there was. For the people in the lower levels this might mean a bigger struggle to receive the support that is need for BIM implementation. It is therefore important that the senior management invests money in education to ensure that BIM can be implemented (Dainty, A. et al, 2015; Bryde, D. 2013). Dainty et al (2015) also enforces that it is necessary to keep the knowledge among the co-workers up-to-date since the technology behind BIM constantly is evolving.

2.4 BIM at the Construction Sites

BIM has been established in the design stages of the construction process. Different consultants make a 3D-model in CAD programmes. The geometry has been in focus, but very important implementations of the models are coordination and collision control (Blom et al., 2013). For the model to be more useful in the production stage, more information needs to be put in the model than needed for collision control.

The use of BIM at the construction sites is starting to spread. It is not uncommon that the workers on site find that traditional drawings do not contain enough information for their usage (Bråthen and Moum, 2016). BIM can therefore function as a complement to traditional drawings to give further information to the workers. It has also been noted that the 3D models make it easier for the workers to see dependencies on other disciplines compared to traditional 2D-drawings. Van Berlo and Natrop (2015) showed in a study that the use of BIM also aided the communication between the site office manager and the construction workers on site. The workers went to the site office and got task specific drawings from the model that showed them more information than traditional drawings. However, this approach was very time consuming every day for the site office manager, since they had to stop their usual work to extract the specific drawings. Other studies have looked at the use of BIM kiosks or stations. The stations, which consists of a interactive screen or computer, are placed on site where the workers can use it when they want (Bråthen and Moum, 2016; Murvold et. al., 2016).

A case study of the Oslo airport construction showed that the reinforcement workers had benefited from the use of BIM. They used tablets out on site to look at the model instead of drawings and appreciated the possibility to look at the reinforcements in different angles where more complex reinforcement should be placed (see figure 3). The time-savings of not having to go back and forth to the site office to get drawings was also mentioned as something appreciated by the workers. The study showed that the appreciation was not affected by the age of the workers. However, the model felt unnecessary when simple reinforcement works were made (Merschbrock and Nordahl-Rolfsen, 2016).

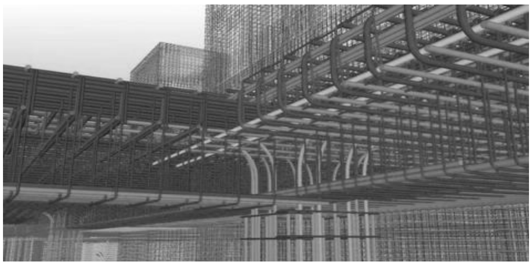

Figure 4: Reinforcement model of the Oslo airport (Merschbrock and Nordahl-Rolfsen, 2016).

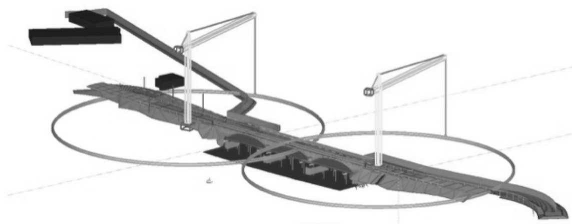

Figure 3: Work site outline of the Röfors bridge (Malmkvist, 2018)

One issue mentioned in the earlier subchapter is how to include the BIM-model in the contract. The Röfors bridge project is an example of how the BIM-model can be incorporated in the contract. The project functioned entirely without paper drawings (see figure 4). Instead of using a standard contract they changed it and gave the BIM-model equal status as the drawing descriptions. This meant that the model was legally binding and what the team on site worked against. One issue with having the model and description as equal was that when they differed it was not clear which should be followed. Since the site was so small these issues were solved on site. They also worked on the production site without printing out any paper. By working with tablets and production views made by the BIM-responsible it was possible to avoid printing paper. The issues they discovered were taking out measurements from the model on site. They solved it by having pre-measured views, but the software for the tablets should become more user friendly. However, having the drawings and production views on the tablets was helpful since the workers never had to look for drawings, since it was easy to access (Malmkvist, 2018).

In the examples above, BIM has only been used as a 3D-model on site. As a way to integrate BIM further in the construction process, 4D-BIM and 5D-BIM have started being used. 4D-BIM implements the time perspective into the BIM-model and 5D-BIM includes economic calculations as well (Jongeling, 2008). By introducing time and economy in the model means that more information has to be included. The Swedish BSAB classification system is one that is frequently used in BIM-models to classify objects. The system consists of tables were construction parts, elements, results and resources are classified (BSAB, 2018). To be able to use BIM in facility management, 6D has now started to come which includes the life-time of the building (Symetri, 2018). However, none of these has yet received a big impact in the construction process and will therefore not be further discussed in the thesis.

2.5 BIM in the Studied Organisation

The studied organization is a large construction company in Sweden, from now on referred to as CC. CC divides its organisation into four to five business areas, that are operating in different regions in the countries where they are doing business. The construction process within the company is divided into five stages; market, calculation and tender, pre-production, production, and warranty. In market they analyse the prospects of new constructions and during calculation and tender they calculate their price for a construction and submit a tendering. Pre-production consists of creating the design and drawings of the building and during production the building is constructed. The final stage, warranty, takes place after the building is finished and consists of taking care of construction mistakes.

The separate business areas and regions manages their own business organisation, which means that the implementation of BIM functions differently in the different regions. In some of the regions, they have employed BIM-expert groups that work with BIM for them and in others, they have focused on training of the projects. The thesis is focused at two business areas, construction (BAC) and housing (BAH), within one region. The two areas have the opportunity to learn from each other since they are operating in the same region. In the studied business areas there is currently to support function existing. Due to the nature of the organisation some comparisons will be made between the business areas in chapter 5.

BIM has been used in the company since 2008, with 3D-models at a start, and they are working towards implementing 5D-BIM. According to a decision made in the early 2010's, BIM shall be implemented into all projects with a cost over a target amount decided by CC's management. CC has developed a BIM-manual as an aid in the development of the BIM-model. They have three levels of detail when it comes to BIM and each level contains all the information from the previous level with added information for that levels specifics. In table 3, CC's detail levels can be seen as well as which of the five LOD's they can be represented by.

CC's level of detail		LOD
M1	Building model with focus on collision control and investigation	LOD 200
M2	Model were planning, quantity extraction and calculations can be made, the detail level in the model should be at 1:100	LOD 300
M3	Highly detailed model that can be used as building documents, with a detail level of 1:50	LOD 400

Table 3: CC's level of detail for BIM-models compared with the five levels of LOD (source: CC BIM-manual)

3 METHOD

There are many different ways of researching and a lot of approaches to use in order to achieve specific goals in a thesis. The research approach chosen as the most suitable one for this thesis is the combination of qualitative and quantitative approach incorporating elements of the deductive approach as well. The research methods used in this thesis is a quantitative questionnaire, with some qualitative questions included, sent out to all members of site management teams within BAC and BAH at CC. Qualitative information intake with a questionnaire and semi-structured interviews were conducted. Below the basic definitions of these approaches as well as the chosen methods of research and analysis of the gathered data will be presented.

3.1 Theoretical Background of Selected Methods

Qualitative approach aims at understanding and export the results of the research done through the visual perception of the people involved in the research, in this case the respondents (Merriam, 2002). Paraskevopoulou-Kollia (2008) describes the qualitative method as the method which the researcher uses to analyse the specific nature, the species of the phenomenon being examined. The researcher should combine in a sensible way data and situations, to interpret them and to make a conclusion from what they observed.

Regarding the quantitative method of analysis, it is related to the selection of numerical data analysed using mathematical methods and specifically it is based on figures and statistical comparisons (Koulaksizi, 2014). Quantitative method includes the measurement and quantification of the data collected during the research of a phenomenon, the classification of the attributes into categories and the creation of statistical models in order to be explained what is observed.

According to Silverman (2006) and Koulaksizi (2014), the main methods of qualitative approach are observation, analysis of texts and documents, interviews and audio or video recording, biographical analysis, case study, ethnography, action research, focus group and content analysis. Moreover, the authors also mention some methods of quantitative approach which are experiments, official statistics, social survey and questionnaires.

About deductive and inductive approaches, in the inductive approach an empirical observation is made in order to reach or create a theory, the approach makes a conclusion from the particular to the general (Graziano and Raulin, 2013). Deductive approach is related to the analysis of the theoretical background of the phenomenon first which ends to empirical studies in order to have the conclusion about the phenomenon observed from the general to the particular (Björk Löf and Kojadionovic, 2012; Gollin, 1998). As it mentioned above, the combination of qualitative and quantitative as well as the deductive approach and the use of interviews and questionnaires were chosen as methods of research for the thesis.

3.2 Questionnaire

Questionnaire is a technique of data collection where the respondents should answer in writing the same set of questions in a specific order. It is usually used to collect data about the knowledge, opinions, views, attitudes etc. of the respondents for a specific topic, when there is large sample and because it is an easy-to-use, standardized, low-cost and low-time technique (Arkoudi and Georgopoulou, 2016).

A questionnaire, in order to be successful, should present in the beginning the defined topic and the purpose of the research, have the appropriate size so as not to initially discourage the respondents and have clear and simple questions in order the respondents to read and complete it easily (Gianopoulos, 2012). As with the questions above, there are structured semi-structured and unstructured questionnaires as well as open-ended and closed questionnaires regarding the types of questions involved (Koulaksizi, 2014).

3.2.1 Preparing the Questionnaire

A questionnaire should have an appropriate structure and coherence for being clear and understandable to the respondents using simple questions and cover the necessary issues for the researchers, include basic instructions and explanations and not take a lot time to do it according to Arkoudi and Georgopoulou (2016). The authors also mention the stages of the preparation process of a questionnaire. The researchers should define the information to be collected, specify the type of the questionnaire which should be used, the content and type of the questions, word the questions and decide their order, test the questionnaire and make the final changes. Moreover, Galanis (2012) points out that if a questionnaire consists of more than one sections, each of which measures different dimensions or concepts, the questions of each section should be clearly defined and distinct from the questions of the other sections to avoid confusion.

In the preparation of the questionnaire for this thesis, a structured questionnaire with the combination of open-ended and closed questions has been chosen for the research and analysis of data. Structured questionnaire has specific questions which respondents should answer, it is well prepared in advance, an easy way to keep the respondents to the topic and to analyse the results. In addition, the current questionnaire consists mainly of closed questions in order to take specific information and the facts about the topic and to minimize the time needed for completing the questionnaire. However, there is an open-ended question at the end of the questionnaire in which the respondents are free to express their opinion and add comments about BIM implementation in order for the research to not have any gaps. In many closed questions there is the possibility for the respondents of making comments if the proposed answer is not desirable, so, in this case, it is a combination of open-ended and closed question. In addition, "multiple choice" and "Yes/No" are the forms of closed questions mainly used in the questionnaire. Likert scale is used to some of them to rate the agreement or disagreement of the respondents regarding specific issues about implementation of BIM (Galanis, 2012). The questionnaire was sent out to 226 supervisors, planning engineers, site managers and others working in the site management teams. To ensure more responses, the questionnaire was made in Swedish and has been carefully translated into English for the analysis part of the thesis.

3.2.2 Analysing the Questionnaire Results

There are several statistical methods which can be used for the analysis of a questionnaire. Some of them could be the linear regression, descriptive statistics, logistic regression as well as analysis of variance (ANOVA), t-test, chi-square test, Pearson's coefficient of correlation, Spearman's rank correlation coefficient, mean, standard deviation, frequency distributions and bivariate analysis (Katsanos and Avouris, 2008; Bryman and Bell, 2011). The methods which will be chosen depends on the type of data and the type of the question. As in the current questionnaire there are different types of questions, "Yes/No" questions and multiple-choice questions, a combination of some of the above methods will be used. These methods are descriptive statistics, ANOVA, chi-square test, Pearson's coefficient of correlation, mean, standard deviation, frequency distributions and bivariate analysis. The results will be presented using graphical method meaning tables, indicators, histograms and charts (Galanis, 2009). Also, SPSS Statistics will be the tool of analysing the data received by the questionnaires.

In detail, for analysing the data taken from Yes/No questions, chi-square method, which is used to find if there are differences between the expected and observed frequencies in one or more categories, and bivariate analysis, which is a simple analysis of determining the relationship between two variables, are the most appropriate methods. The data from multiple choices questions will be analysed using ANOVA, as this method is more suitable for comparing more than three variables, as well as logistic regression, as it analyses the data in which there are more than one independent variables. Before starting the analysis of the data, a coding table will be useful for organising them and the process to become clear and effective.

3.3 Interviews

Based on Silverman (2006), interview is a low-cost method in terms of time and resources with which the researcher can explore the beliefs, values, views, experiences and attitudes of interviewees in depth. An interview can be structured, semi-structured or unstructured (Koulaksizi, 2014). Wilson (2012) mentions that in a structured interview, the researcher should ask only the predefined questions to all interviewees with the same structured way. This type of interview is characterized by the limits which has, as the researcher should follow a strict and coherent structure in each interview, as well as they do not have the opportunity of further discussion.

The authors above also state that semi-structured interviews are more flexible than structured. The researcher should prepare some questions to ask but, mainly, use them as a guidance for keeping the interview in a flow and helping interviewees to talk about a specific topic, without following a structured set of these questions. Finally, an unstructured interview is more about a conversation about a specific topic and is characterized by its flexibility and no limits discussion. However, the analysis of the data of an unstructured interview is more difficult and complicated than the other two types of interview.

In the thesis, the type of interview used is on-site semi-structured interviews to members of site management teams within construction such as site managers, supervisors and planning engineers. The method was chosen because it gives the interviewees the ability to express their opinions and views about BIM implementation in a way which will keep them on the topic, but in the same time have flexibility and further questions can be asked to clarify. Interviewees from different projects and with different roles as well as interviews in people who work in the same project but in different positions are chosen. This decision was made in order to see if there are differences or similarities in the way they work and their abilities, knowledge and attitude regarding the use of BIM in their project. Nine interviews were performed in this thesis and was done mainly in English, with the opportunity for the interviewees to answer in Swedish due to difficulties with technical terms. The answers were carefully translated into English before the analysis. The interviews lasted between 40 minutes to one hour, including a combination of open-ended and closed questions, as it refers below.

3.3.1 Preparing Interview Questions

In an interview, the questions are divided into two categories: open-ended and closed questions (Silverman, 2006). Open-ended questions are usually formulated with "what" or "how" in order to give the interviewee the chance to develop their view in a topic in more detail. Questions as these can help them to start talking about a specific topic. The researcher can focus on specific facts and feelings of the interviewee, be informed about how the interviewee thinks, decides and acts about a topic and an occasion (Britten, 1995). Closed questions provide specific information about a topic, focus on the fact and not the feeling of the interviewee. The researcher pre-defines the answers which are mainly short, as they can be answered with yes, no or with a few words (Galanis, 2012).

In the preparation of the interview questions for the thesis, a combination of open-ended and closed questions was found to be the most suitable one. In the beginning of interviews there are closed questions in order to have detailed information about the interviewees such as educational and work background and their knowledge about BIM, and then more open-ended questions follow in order to have more information about the views and feelings of interviewees about BIM and its implementation. Also, the interviews start with questions which are easy for the interviewees to answer and subsequently the level of difficulty and demand starts to be increased. Moreover, the questions were prepared in such a way that their content was simple and the structure clear for the interviewees in order to contribute to the flow of the interviews.

3.3.2 Analysing the Interview Results

The results of the interviews will give the general opinions and thoughts of the interviewees about BIM implementation in the production phase. These results will help with developing future research questions and suggestions for improvement. There are many descriptive qualitative approaches of analysing the results such as descriptive phenomenology, content analysis, thematic analysis, grounded theory and hermeneutic phenomenology (Vaismoradi et al., 2013).

The most commonly used approaches are content and thematic analysis. Content analysis is an approach of analysing a text in a systematic and replicable way, coding and categorizing the data in order to explore, describe patterns, the characteristics and the main features of the text (Vaismoradi et al., 2013). Thematic analysis is about understanding the overall themes in the data, an approach of identifying, analysing and interpreting the patterns and key features of qualitative data (Clarke and Braun, 2016).

Both content and thematic analysis are similar to each other as they have the same aim, to analyse the transcription of the interviews regarding who is doing what, to whom and how and learn about the behaviour and attitudes of interviewees. This is done by dividing the text into small descriptive sections of content and searching for patterns and themes. Content analysis has more to do with the description of the data in a conceptual form, as representations of images and expressions, while thematic analysis has more to do with the description of various aspects of the topic (Vaismoradi et al., 2013). Moreover, content analysis is related to symbols and messages information interceded between people, while thematic analysis gives the methodical characteristic of content analysis and the ability to the researcher to combine their meaning to their specific context (Vaismoradi et al., 2013). Regarding content analysis, it is possible to miss the meaning from the context if the frequent use of a code is counted to find important meanings in the text because a word may be repeated as it is significant for the interviewee about the current project or they just want to speak more about this. In addition, the process of data analysis in content and thematic analysis the researchers follow are similar to each other. However, thematic analysis is more analytical, has a drawing thematic map as well as more clear steps in the phase of organizing the data, such as generating initial codes, defining and naming themes, reviewing and searching for themes. Content analysis puts all these sub-categories into one category.

Based on the characteristics of each approach above, the most suitable one for this thesis is the thematic analysis approach. It was chosen because the focus should be more on the various aspects regarding implementation of BIM and it has clear steps of process which can be followed minimizing the errors, something which could be risky if content analysis is used in combination with the risk of missing context. A thematic mind-map was developed and can be seen as total in figure 5 as well as in more detail in appendix III.

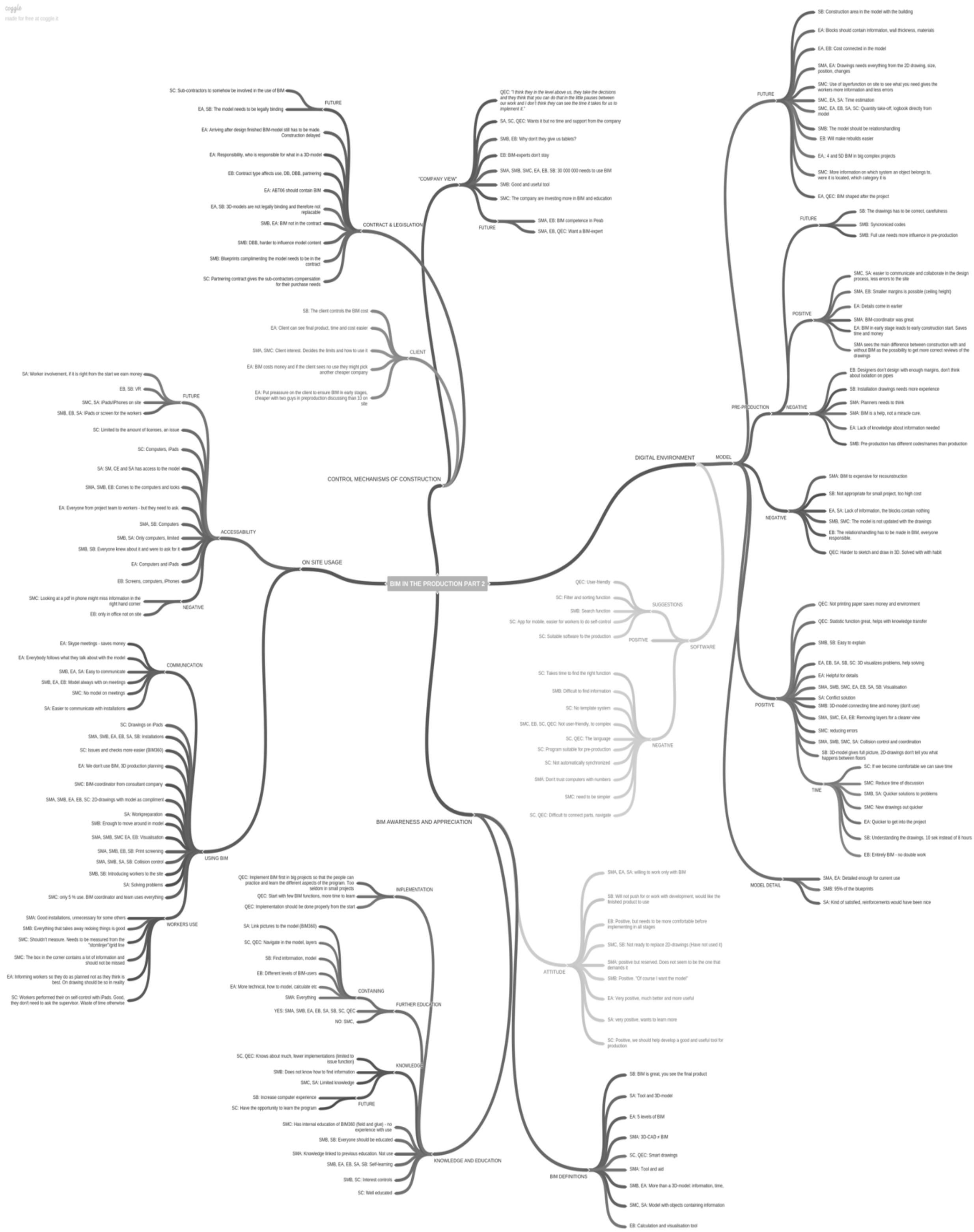

Figure 5: Mind-map of thematic analysis

3.4 Research Ethics

The importance of research for society and ecology is great. Research ethics constitute an important part of the research and therefore also the thesis process. During the interviews, questionnaires and report of the thesis there were some ethical principles in mind which influenced the way of performing the interviews, preparing the questionnaires and writing the report. The main principles taken into mind were the honesty of the data written in the report meaning that there is no fake data, that the research is characterised of objectivity, there is consistency of action, carefulness in order to avoid mistakes during the research and data selection, respect for intellectual property, social responsibility meaning that this thesis become in order to promote the social good and education and finally compliance with the laws and rules (Resnik, 2015).

During the interviews, all the interviewees were informed that the interviews were anonymous, and the questions are characterized of objectivity. Also, they were made in a way which each interviewee could answer whatever they want, not keeping them in a specific direction. They were free to answer what they believe about the subject knowing that there will not be any mention of company details and data in the report. The interviewees gave their permission to record them before the start of each interview. In addition, all the data written in the report are visible as they can be easily found on the reference part of the report. However, anonymity of the construction company is maintained, and its data are not presented. Also, during the interviews and questionnaires analysis professional and personal opinions should be clearly distinguished for having objective and correct results. Moreover, the research should benefit the company, the participants in the research, the reader and the scientific community as well. The questionnaires were also anonymous and sent via email and not via post to the participants in order to protect the environment from the unnecessary paper consumption.

4 RESULTS AND ANALYSIS

In this chapter the results from the questionnaire and interviews will be presented.

4.1 Questionnaire

The questionnaire was sent out to 226 possible respondents and 80 answers were given, an answer frequency of 35,4%. The expected results for a questionnaire send out to working people in the construction industry are 25-35%, therefore this is deemed as good answer frequency (Fellows and Liu, 2015). Among the respondents the age, education, work experience and position spread were satisfactory, which shows that many different people took interest in responding to the questionnaire. Of the respondents 28% were site managers, 28% planning engineers, 40% supervisors, and 4% had other positions out in construction, such as project manager or controller.

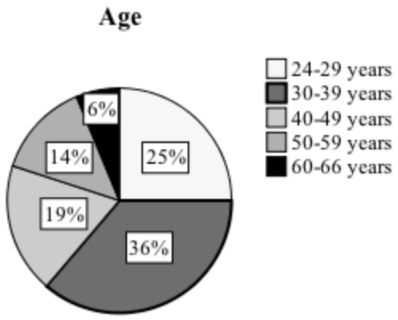

Chart 1: Age

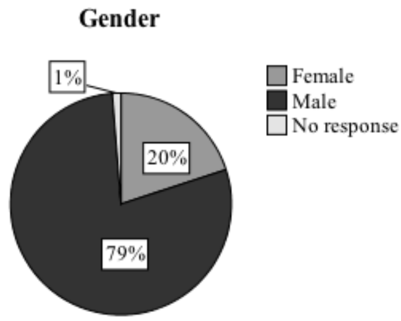

Chart 3: Gender

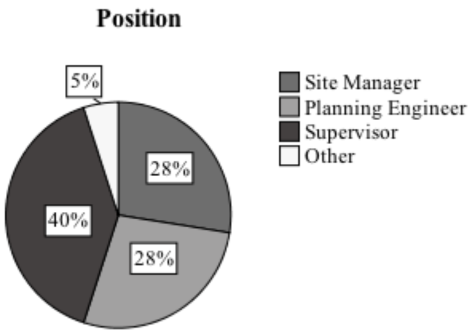

Chart 2: Position

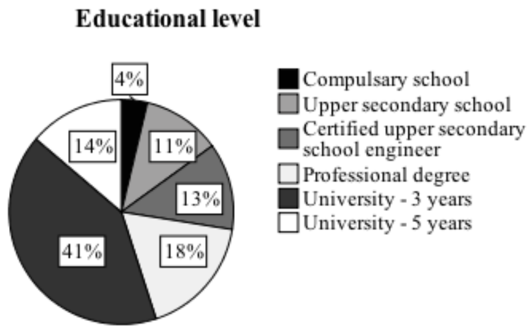

Chart 4: Educational level

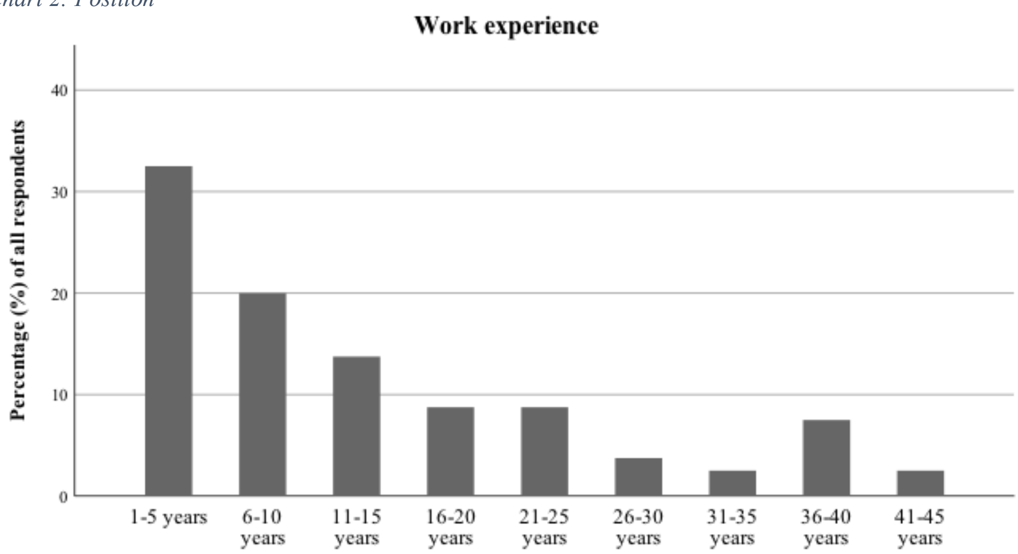

Chart 5: Work experience in year categories

4.1.1 BIM Education in Production

Of the respondents, 84% are familiar with BIM and 16% are not or unsure. 79% of the respondents have not received any education in BIM, 16% have gotten an internal education and 5% external. The answers do not refer to BIM education at school. Of the respondents that had received education everyone wanted or answered maybe about receiving further education, but no one answered “No” on the question. Of the respondents without education 13% said that they did not want education and 22% answered maybe. 65% wanted to have a BIM education.

30% of the respondents who had received any education in BIM, had it four or more years ago, but the number of respondents who are recently educated in BIM is also high. Also, the education they had lasted mainly a few hours or days, only the 23% had education which lasted more than a week. The 95% of the respondents answered that education contained mainly navigation in BIM, how to take out information from the model (76%), sort among building parts and layers (71%) and take measurements (65%). Less respondents answered that their education was related also to production planning and quantity take-off. Most of the respondents are satisfied with the content of the education in BIM, 12% are dissatisfied and 17% are unsure. Also, 47% of the respondents answered that the education they had in BIM was useful enough, 35% had a neutral attitude, 12% answered that it was very useful and 6% that it was not useful at all. However, almost everyone (94%) would like to have more education in BIM to learn more about navigation in BIM, production planning and quantity take-off, how to take out information from the model, sort among building parts and layers, take measurements.

Regarding the respondents who do not have any education in BIM, 65% of them would like to have an education in BIM and 22% answered maybe. Most of them would like to know more about navigation in BIM, production planning and quantity take-off, how to take out information from the model, sort among building parts and layers, take measurements, different types of inspections and have a guide of how to do the collaboration to model

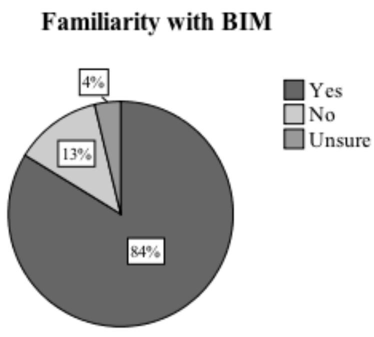

Chart 6: Familiarity with BIM

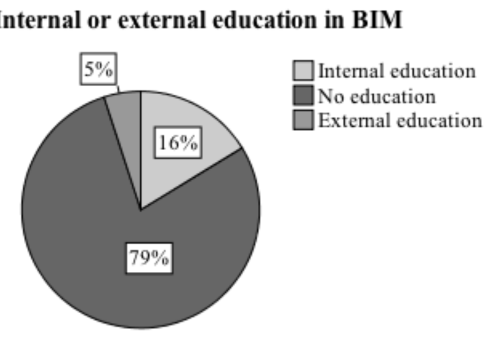

Chart 7: BIM education

4.1.2 BIM Use in Production

As chart 8 and 9 shows, a large amount of the respondents has enough knowledge in BIM and have a positive attitude towards it. Also, 61% of the respondents have worked in a project using BIM and the model was better than they thought. The tools most of them mainly use are computers but also screens/projectors in meeting rooms and tablets. Some use their mobile phones, touchscreens and smartboards as well (chart 10). The software they mainly use is Solibri Model Viewer and are very satisfied with it and then Revit, Revit-viewer and SketchUp follow. There are also some respondents who commented that they use BIM360, Solibri Model Checker and Bluebeam. Most of the respondents find that BIM is a bit complex and not user-friendly especially with regard to make the planning, work preparation, quantity take-off, measurements, use the model on the work site, and find information such as material types. In addition, chart 11 shows how the different co-workers use BIM and chart 12 what they have used BIM for in production.

The respondents were asked to answer what they want to use BIM for in the future. Some options were presented and also the opportunities to add other areas in which they want continued use or start to use. The results are presented below in chart 13 and table 4. The respondents also got to answer on the question which tools they would like to able to use in production as seen in chart 14. The most wanted tools were computer, screen and tablet.

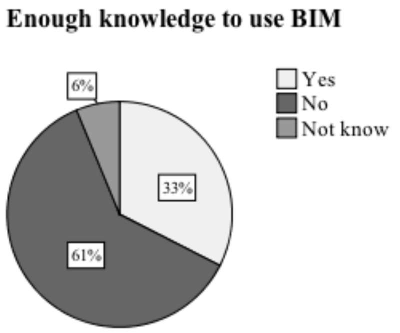

Chart 8: Perceived knowledge on how to use BIM at the construction site

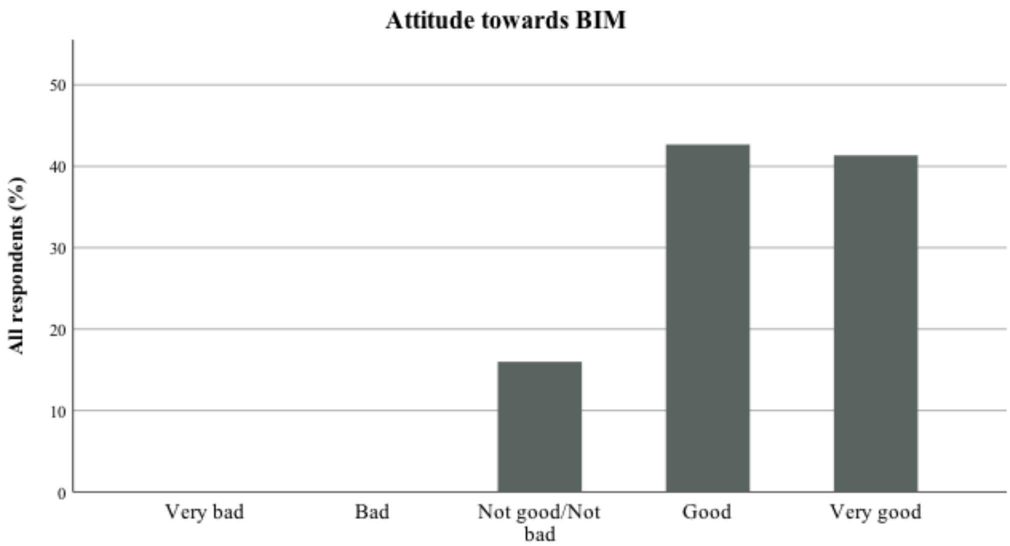

Chart 9: Attitude towards BIM

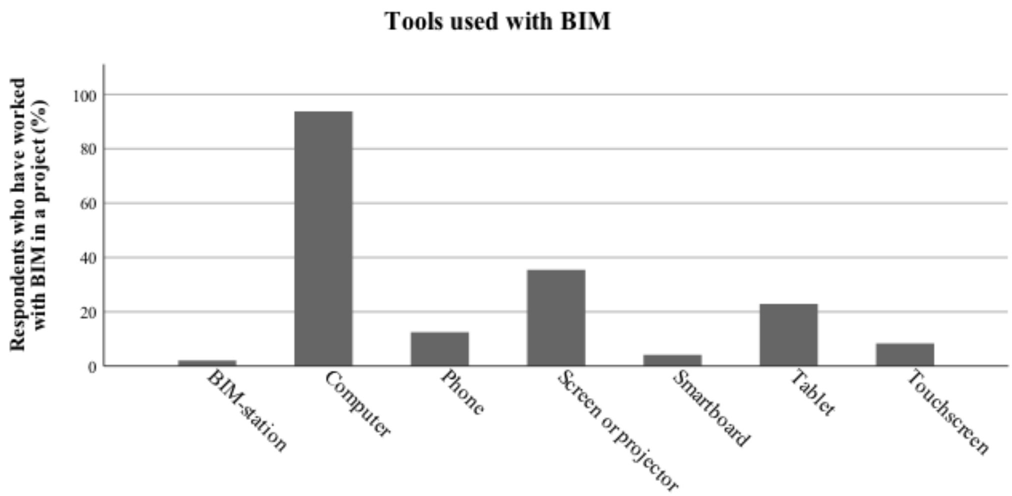

Chart 10: Currently used tools at the construction sites to view BIM

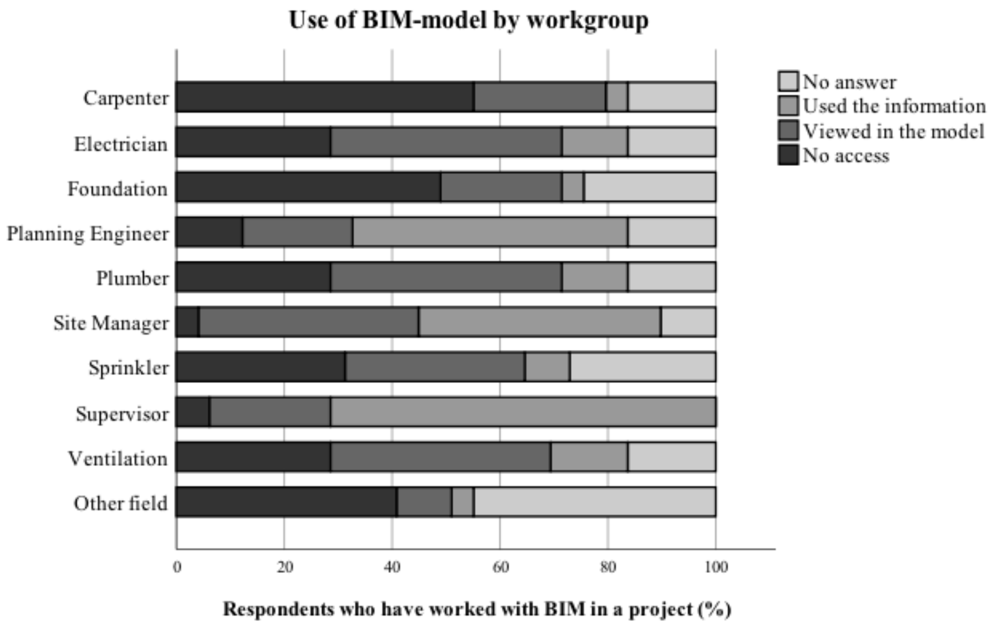

Chart 11: How different workgroups used the BIM-model on site

Chart 12: Current use of BIM at the construction sites

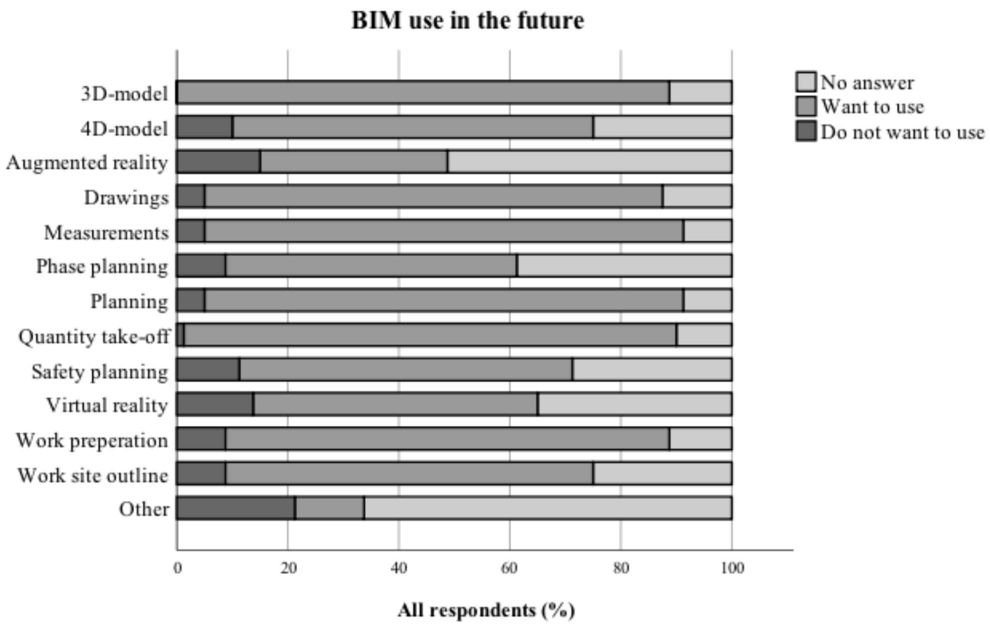

Chart 13: Wished future use of BIM at the construction sites

Other use area
Collision control of drawings
Collision control of installations
Rounds and inspections
Watch fastening details and material transitions
Inspection and safety rounds
Calculation and project economy

Table 4: Other use areas of BIM in construction

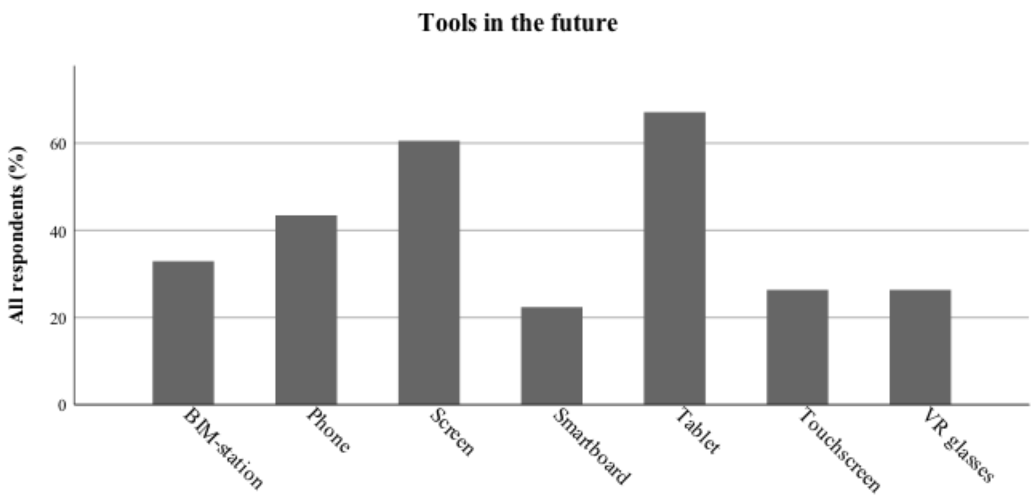

Chart 14: Wished tools for the future to use with BIM at the construction site

4.1.3 Definition and Comments

The respondents got to answer which stages they find BIM useful in. The options were based on the stages that CC uses. It was possible to select several stages or the option all stages. 41% of the respondents considered BIM useful in all stages and cumulative of the answers showed that BIM was deemed most useful in the pre-production and production stages (chart 15).

The respondents got seven different options of BIM definitions, the opportunity to add their own definition and to select several definitions. 76 of the 80 respondents answered on the question. The majority of the respondents selected several of the options. As the graph below shows the people in production define BIM mainly as a work tool, 3D-model, visualization tool and information database (chart 16). They were able to make a general comment about BIM if there was something that they wanted to add. In the table 5 below the 15 comments given are written.

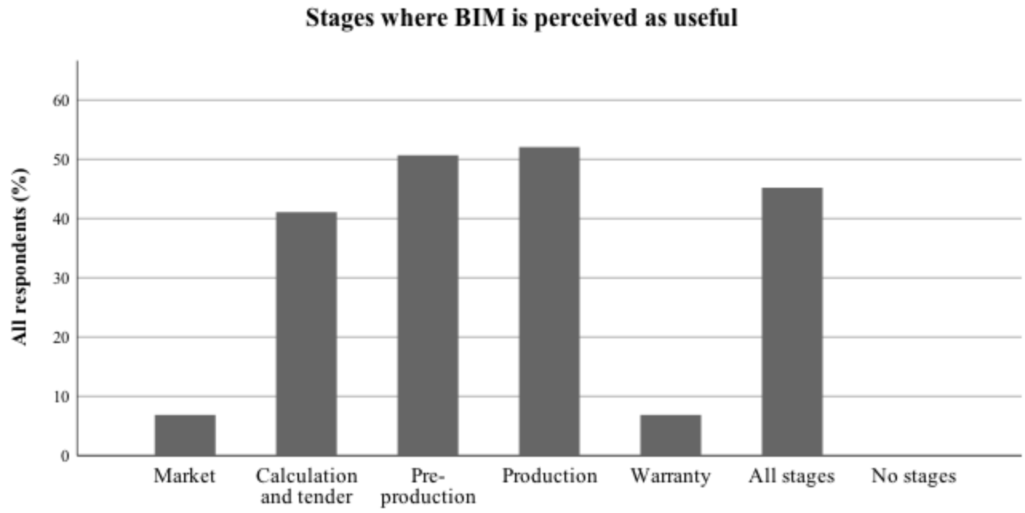

Chart 15: Stages where BIM is perceived as useful

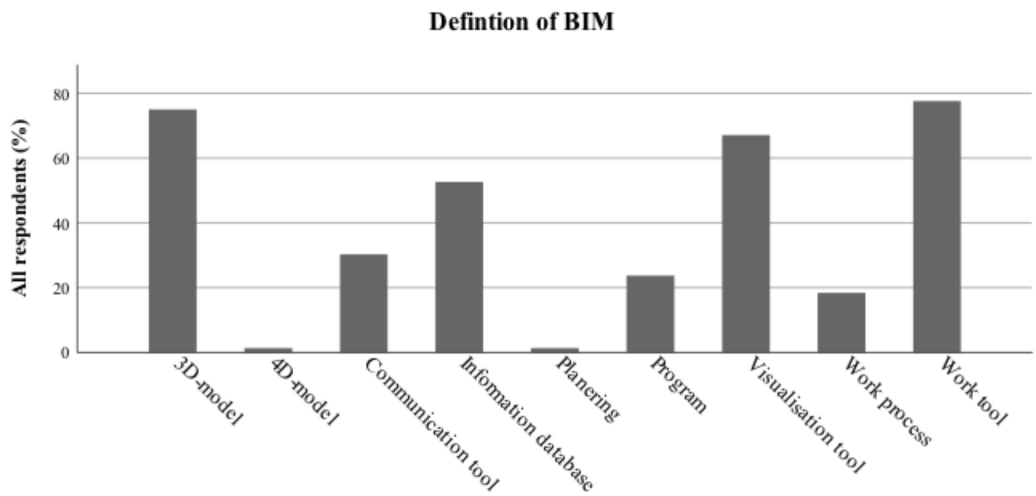

Chart 16: Definition of BIM

Open answers on BIM	
1	Shall this come out in "reality" it has to be as user friendly as possible. Everyone is not that familiar in the computer sphere, so it shall really be so easy it is possible to use.
2	I think it will be a great tool when everyone can use it and will use it.
3	Believe in BIM, just as well to follow the future from the start.
4	This should exist more in the pre-production/production for smaller projects as well. One problem that exists is that system document etc is first made in 2D instead of 3D and that it later is seen as a cost to make it in 3D for continued pre-production.
5	The weakest link is all of our subcontractors that performs most of the production.
6	My own opinion is that the application is to complex today to be able to use in all its parts. Implementation should be limited to a few areas to later be increased.
7	When will it start? Have heard for 6 years that BIM is a revolution for the construction industry but has yet not seen it used in production. Still you print out drawings and measure with ruler. What is the problem, why is it not used?
8	To be able to use it fully an extensive education is needed.
9	Good in some project as new production, though premium in reconstruction.
10	It should go faster, we are behind!
11	Should be more accessible. A phone or something that you always bring along with you.
12	Do not know how "good" BIM is since I have never worked with it.
13	I think we are far too behind with the digitalisation and therefore we started using BIM360 for work preparation, self-control, inspections and safety checks. We on CC should be one of the leading companies in the digitalisation but it feels like we have not gotten anywhere yet.
14	Older persons usually do not have the ability to use BIM, which demands a lot of work for younger (often new supervisors?) since much of the information is there if you only know how to find it. Is troublesome if it takes so much time to help other people to navigate in the model that you should start charge for it.
15	I think that it requires very clear information to the construction sites what it can be used for and how it is used, and that the management or similar puts pressure on the use so that it implements fast.

Table 5: Open answers from questionnaire

4.1.4 Correlations

In this section, some interesting correlations of the variables of the questionnaires are going to be presented. There is a correlation between age and degree. Younger employees are those who are more educated having a professional or university degree while people mainly over 45 have finished the upper secondary school. Also, the familiarity with BIM is related to age of the employees as elder people are less familiar or unsure towards it as well as to educational level as people with lower education are less familiar with BIM.

There is also a correlation between work experience and degree. People who have more years of work experience in the company are those who do not have a professional or university degree, the less educated. Indeed, those employees who have around 40 years of working experience have only finished the compulsory school. Furthermore, there is a correlation between work experience and familiarity with BIM showing that people with a lot of years of working experience are not familiar with or unsure about BIM.

Regarding the education some employees had about BIM, the longer education lasted, the more useful the content was and what was needed. Also, most of the respondents believe that the education was useful, and the content was what they needed but there are also many who are neutral about the education and they believe negative opinion about the content. People who have enough knowledge about BIM they have more positive point of view about the education on BIM and they would also like to have further education. In addition, people who have positive attitude towards BIM they also have positive point of view regarding the usefulness of BIM in production.

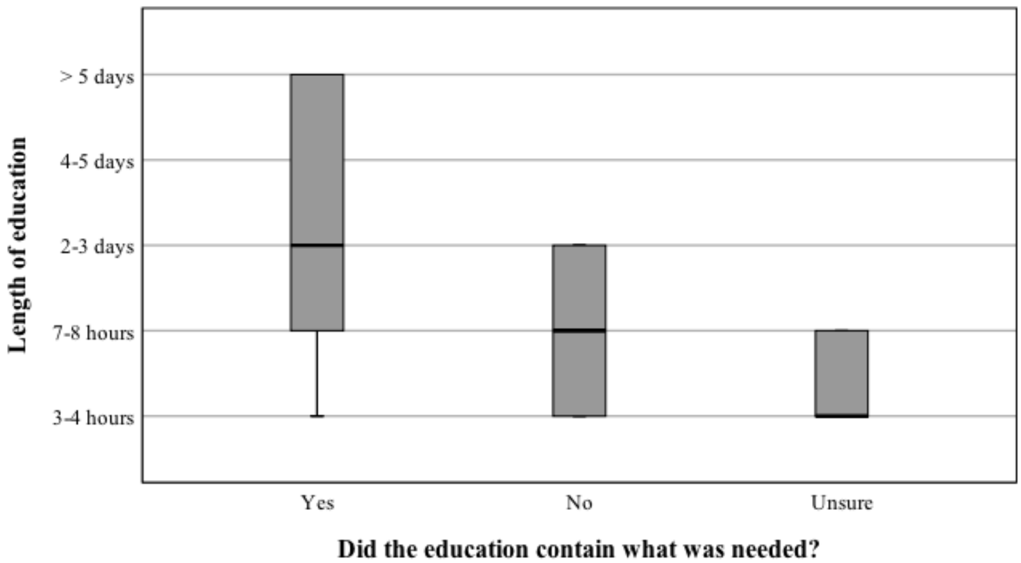

Chart 17: Correlation between length of BIM education and if the education contained the necessary information

4.2 Interviews

In this chapter the results of the interviews will be presented, starting with a presentation of the nine interviewees followed by the results. Four different themes emerged during the analysis of the interviews and the results will be presented according to these themes; control mechanisms of construction, BIM awareness and appreciation, on site usage and digital environment.

4.2.1 Presentation of the Interviewees

In this section the nine different interviewees will be presented including which of the two business areas they work in, construction (BAC) or housing (BAH). Three site managers, two planning engineers and four supervisors were interviewed to get deeper knowledge of the view of BIM at the sites.

Site manager A

Site manager A (SMA) is an upper secondary school engineer that has previous experience as a stone worker before starting as a supervisor at CC in and then moved on to site manager at BAC. Currently SMA was not involved in any BIM related projects but has been working on an office building were the BIM 3D-model was extensively used during construction as a way to visualise the work.

Site manager B

Site manager B (SMB) started at CC as supervisor and then became a site manager at BAC. SMB has a bachelor's in civil engineering. Their current project uses BIM that has been provided by the client since it is a design-build contract. The primary use of the model is to visualize issues during construction and is always open on SMB's computer.

Site manager C

Site manager C (SMC) has a civil engineering degree and started as a supervisor at CC, before becoming a site manager at BAC. SMC has not used BIM in any project but has had an education in BIM360. The project SMC is currently working on is going to use BIM, but to what extent has not been decided.

Planning engineer A

Planning engineer A (PEA) has worked as a purchaser for large projects and are now working as planning engineer and project manager for different projects at BAH. PEA has not received any education with BIM and is self-learned within the program. They work on incorporating BIM in all projects, especially in the early stages.

Planning engineer B

Planning engineer B (PEB) started their career as a carpenter, continued as a supervisor and then site manager, before becoming a planning engineer at CC at BAC. PEB has no formal education in BIM other than a two-hour session with the former BIM-expert at CC. They want to have a BIM-expert in every project and sees BIM as the future for construction.

Supervisor A

Supervisor A (SA) has a long experience as a concrete worker before becoming a supervisor at BAC. The knowledge SA has of BIM comes from the site manager that SA works with. SA sees usefulness in BIM, both from the perspective of a supervisor and a worker.

Supervisor B

Supervisor B (SB) has previously worked as a carpenter and purchaser before working as a supervisor at CC at BAH. They have no education with BIM and is currently working on the first project that has involved BIM.

Supervisor C

Supervisor C (SC) has studied three years at the university and started then at CC at BAH as a supervisor. At CC, SC got an education of BIM360 and has worked with BIM in several projects. They have mainly used functions for inspections and checklists, that can be connected with different subcontractors and members of the site team.

Quality and environmental coordinator

The quality and environmental coordinator (QEC) has worked in the IT industry before retraining to a construction engineer and starting at CC at BAH. QEC has worked with BIM in the late stages of a previous project were they mainly used it for inspections and self-control.

4.2.2 Control Mechanisms of Construction

The interviewees were aware of the target amount within CC that controls if BIM is used or not. However, there was a bit of confusion on which the target amount was, with the planning engineer being confident on an amount and the supervisors being unsure. The company's target amount was seen as a way of pushing BIM into the construction, but that the focus is put on pre-production. It is deemed a good and useful tool during the construction process, but the site management teams do not feel the support from CC to implement it. The general view was that CC wants to enforce it but are not willing to provide the time needed for the implementation.

> *"I think they in the level above us, they take the decisions and they think that you can do that in the little pauses between our work and I don't think they can see the time it takes for us to implement it."*
>
> *QEC*

The lack of a support function within the company was also brought up. According to the interviewees there were BIM-experts within CC, but they quit after a while. Something that makes it hard for them when they have questions about how to navigate and find their way in the software they are using. SC and QEC had the opportunity during one project to have video-meetings with an expert, but these were weeks apart, they would forget the questions they had and there was no help directly with small things for them. Both PEA and PEB said that they want a BIM coordinator in their project and SMA said that the BIM coordinator they had was the reason for the project becoming as good as possible. However, this function is usually placed on a consultant or someone that manages it as well as other duties. The most common combination was planning engineer and BIM responsible on site, which meant that BIM sometimes were not given enough time. According to the interviewees BIM competence needs to exist within the company and not rely on consultants.

There were also questions about the accessibility to tablets that was most prominently brought up by SMB and PEB, which indicated that the issue of informing how to get access to tablets can be seen within BAC. All of the interviewees in BAH had access to tablets and appreciated the mobility they gave. The same views of the mobility that a tablet gives can be seen in comment 11 in table 5.

Other things that affects the BIM use within CC are the client and the contracts. According to the interviewees, BIM costs more money than the usual way of making drawings, which means that the client has to pay more money for projects using BIM. Since the client controls the costs it is possible that they instead go for another company that has a lower bid. It is also necessary for a good implementation to introduce BIM early in the construction process. The earlier BIM is introduced the earlier some problems are solved. This, on the other hand, means a higher risk for the client, since they will lose more money if the project gets stuck in the pre-production stage. On the other hand, it will be cheaper for the client in the end to have fewer people solving the problems in the pre-production than having more people solving them on site according to PEA. If the client is very interested in BIM they will ask for BIM in the process and if there is no interest, they do not care. The interviewees also pointed out that the opportunity to see the finished product, cost and time easier. Another suggestion to make it easier and more understandable was to make a time-lapse of the production phase, where it is possible to show when they will have gotten to a certain point in the construction of a building.

The final thing that controls the production phase is the contract type that is used. The most common to use was turnkey contracts, that gives the company control over the entire construction process. For the interviewees this was seen as beneficial since they have the opportunity to affect the BIM-model more. Design-Bid-Build contracts was seen as more complicated for the interviewees since they come in after the design is finished. In some cases, a BIM-model has not been made and sometimes it has, but they have no ability to influence the content of the BIM-model. When the model is not made they sometimes have to make one to be able to solve issues or because the project is worth above CC’s target amount. Then the start of the production is put on hold for a while to make the model.

Other issues with contracts is who has the responsibility for the model. It has to be clarified in the contract who is going to be responsible for which part of the model and how that works. It was also seen as an issue for the interviewees that the model is not in the contract and that is something that stops them from using the model fully. The model is not updated with the drawings in any of the interviewees projects, which makes it unreliable to build with. The responsibility issue needs to be clarified for them since when asked who was responsible, SMB answered:

"Probably me, I'm in charge of making sure that we always work on the latest version of the drawings. But again, the model in this project isn't by contract, it doesn't say anywhere in our contract that the model is the legal drawing. It is not the one we should build after, we are going to build after the blueprints. So, I'm in charge of that everything in the blueprint binder is up to date and I don't do much with the model."

SMB

There was a general view that the Swedish contract type for turnkey contracts, ABT06, needs to be updated to include BIM. To be able to use BIM fully, the model has to be the construction documents. For the future, they also felt the need to include the subcontractors more with BIM since they are doing most of the work on site. Partnering contracts with the subcontractors was used in one project to ensure that they felt a higher interest in using it.

4.2.3 BIM Awareness and Appreciation

Some of the interviewees had enough knowledge about BIM and some others less or no knowledge. To the question about the definition of BIM, all of them answered that BIM is a 3D-model. Some added that it is a tool, some others that it is smart drawings, a calculation and visualization tool or a model with objects containing information. It was interesting that some of the interviewees said that BIM is something more than just a 3D-model as it contains information and time or that it is a 5D-model.

The main problem found from the interviews regarding the knowledge the interviewees had about BIM was that some interviewees even though they knew a lot about the model, they did not implement and use it while some others had limited knowledge about it. Some of them were well educated while others were self-learned. The interviewees had knowledge about different BIM software, something which created misunderstandings, errors and confusion within the project team.

To implement BIM it is important to start with few BIM functions, giving time to learn them, and do it properly from the start. When implementing BIM in smaller projects, the different functions are used too seldom to learn them, therefore it is better to implement BIM in larger projects as stated by QEC:

"BIM should first be done mainly in big projects so that the people can practice and learn the different aspects of the program."

QEC

In addition, the interviewees, except for SMC who recently went through an education, would like to have further education in BIM. They would like to learn about how to link pictures in the model, to navigate, how to use the different layers of a drawing, as well as more technical aspects such as how to model, to calculate and to find information. Several interviewees thought that it should be different educations for different levels of BIM-users, since everyone does not have the same needs.

Furthermore, most of the interviewees had very positive attitude on BIM. They were willing to work only with BIM, developing a good and useful tool for production. But firstly, they should have better knowledge about the model and need to be more comfortable before implementing it in all stages. However, some of the interviewees are not ready to replace 2D-drawings, since they are not yet comfortable working in 3D and are used to the 2D-drawings.

4.2.4 On Site Usage

Of the interviewees, only one had not worked in a project utilising BIM. However, that person was going to start utilizing BIM in their current project. The most common way to display the model was via a computer at the site office, as can be seen in the questionnaire responses (see chapter 4.1.2). According to the interviewees the model was not available to everyone on site, most of the people knew about it and the workers came in and asked to use it. The people that usually had permanent access were the site manager, planning engineer and interested supervisors. The supervisors that used the model was the ones that showed interest, more commonly the younger supervisors. Some reasons were the lack of interest and computer skills of the older supervisors.

The main current use of BIM on site is to look at the 3D-model to easier visualise the project. One of the interviewees said:

> *"We do not work with BIM, we do 3D production planning."*
>
> *PEB*

The reason for the statement is that they are not using any other feature than looking at the model and use it as a visual aid. There was only two of the interviewees that used BIM in another way, by having checklists and inspections digital. That feature was highly liked, even though they started out with a lot of it and therefore had a hard time to learn all the aspects. By visualising everybody quickly gets the same picture, something that according to the interviewees both saved time and helped with a common understanding of the project.

> *"The best carpenter they had the ability to see the building before it was built… …and BIM I think is going to make it easy for everyone to see this is how it's going to look like. So, they can see the problem before it even is a problem…"*
>
> *SB*

> *"This thing with the 3D-model takes you and the plumber ten seconds to understand, instead of taking them eight hours to read all the 2D drawings and then themselves begin to think how it looks, since they cannot see how the pipes are placed. There are two markings in different places on the drawings, but it is not possible to see if the curvature is low or high in the ceiling. Then he has to look at the architecture drawing to see that there is a small niche in the ceiling and then it is clear that it has to go there. The time save to put the workers into the project, it is awesome."*
>
> *SB*

The common understanding was especially useful when it came to the co-drawn drawings. With every discipline drawn in it, it can be hard to separate the different installations from each other. Something that the interviewees presented as something very helpful.

> *"...you get a totally different visual picture of it, when you have a normal co-drawn drawing on pretty many installations you have to scale it up to A0 to even see that there are different installations."*
>
> *SMA*

When looking at the worker use, the interviewees all agreed that installations had the best use of BIM since it clarifies how to interpret the drawings. By rotating in the 3D-model it is possible to see different angles. The interviewees also used the model to take out their own sections where they needed it and thereby, got more useful sections to work with.

> "*You can show the guys or the girls on site where they are, you can show them that this is how it should be, and if they have any problem you can go inside the model and you can see what the easiest way is to do things. I think that would be really helpful.*"
>
> *SA*

There were divided opinions on how and how much the workers should be involved with the use of the model. The general view was that using the model is unnecessary for carpenters, painters and floor-layers, however, the ones working with installations was seen as having the most use of it. Many issues were solved by looking at the 3D-model instead of trying to interpret the 2D-drawings. But according to some of the interviewees, it would not matter which work group a worker belongs to if using the model helped them to avoid mistakes. However, the current state of involvement was very limited to looking at the 3D-model and using print screens. None of the projects had something on site with the model available on for the workers. They had to go into the site office and speak with someone that had access to the model to view it. In one project the workers did their own self-checks with the aid of tablets that they borrowed from the site office and it was something that saved time for the supervisors since it is one of their normal tasks.

There are also the issues with the site manager being responsible for that the building is done according to the construction documents. They need to be certain that workers do not miss essential information. However, the interviewees felt positive about moving towards a complete use of the 3D-model without any 2D-drawings. To do this they felt that they needed more education and to get used to working with the 3D-model.

> *"I want to use 3D as a compliment to 2D-drawings to make an easy understanding on how things look when you are standing in the room. I understand the 3D-drawings better because it is more visualized, but I work faster with a 2D-drawing."*
>
> *SC*

There are also the issues with the site manager being responsible for that the building is done according to the legal documents. They need to be certain that workers do not miss information that is essential.

4.2.5 Digital Environment

Regarding the BIM software, the interviewees think it is un-user-friendly and too complex for their needs. There are difficulties to find the information, to connect parts and to navigate something that takes a lot of time from their work. As of now there is no template system in work to organize the data contained within the BIM-model. Some more negative factors are the language, the software is not automatically synchronized and made for pre-production. Therefore, the software used on site, is not adopted to the needs of the production phase.

The interviewees wanted a more user-friendly BIM software. Some things that could be improved were better filter, search and sorting functions. In production, those aspects are important. Another way to have a more suitable production-oriented software was to make an app for mobile devices, as it would be easier for workers to do self-control, get the model to the site and simplify the supervisors work since they will have all the information they need with them.

The model detail level was deemed satisfactory, as it contained the 95% of the blueprints. Some positive aspects of the model are that the 3D-level gives a full picture of the final product as well as what happens between floors. It also helps visualizing details which aids in problem solving and reduces conflicts and error since the user can remove layers in order to have a clearer view. QEC mentioned the statistic function in BIM360 as very helpful with knowledge transfer to the next project. Also, the fact that the model reduces the printing of papers saves money and it is environmental friendly.

Also, the model reduces time at the site; it is faster to understand the model than 2D-drawings, discussion time is reduced, solutions to problems are found faster, new drawings are provided quicker, it is easier to get into the project and the user does not do double work. At the moment the time reduction was not there but as SC mentioned:

> *"If we become comfortable with the model, we can save time."*
>
> *SC*

However, interviewees mentioned some negative aspects of the model. SMA said that BIM is too expensive for reconstruction and SB said the same regarding too small projects. Some other problems with the model are the lack of information in the building components, that it is hard to find the information and the difficulty of sketching and drawing in three dimensions.

In addition, the model is more suitable for the pre-production phase. It simplifies the communication and collaboration in the design process creating less errors on the production site, details come in earlier and smaller margins are possible. To ensure that the collaboration can take place they should work with IFC, something that PEA has enforced in many projects. By using IFC the designers can use the software they feel most comfortable with and still produce a complete model. If BIM is introduced in early stages, the team will get more correct reviews of the drawings and it will lead to earlier start of the building construction, saving time and money. EB, although, mentioned that designers sometimes do not design with enough margins, for example, not taking the pipe insulation into consideration, which leads to reduced space in the ceiling and probable collisions with other installations. Most issues were with installation drawings, where it seems to be a lack of experience in drawing in BIM. There is also a lack of knowledge about what information is needed and different codes/names are used in pre-production and the production phase. However, this can be changed in the future by being more careful about the drawing to be correct and using synchronize codes through the entire production chain. To be able to use BIM to the full extent in production they need to have more influence in the pre-production phase, since they then can make sure that the production margins are taking into consideration.

> *"BIM is a help, not a miracle cure."*
>
> *SMA*

Some future suggestions for the model taken from the interviews were following:

- not only the building but the entire construction site is needed in the model
- construction components should contain information, wall thickness and materials
- cost should be connected in the model
- drawings need everything from the 2D drawing such as size, position and changes
- layer function should be used on site giving the workers more information and having less errors
- time estimation is needed
- quantity take-off and a logbook (containing all the materials built into the building) directly from the model are very important
- 4D and 5D should be used in big complex projects
- more information is needed regarding on which system an object belongs to, where it is located, which category it is
- the model should be shaped after the project

5 DISCUSSION

In this chapter, the theoretical background and the results from the conducted interviews and questionnaire will be discussed. The authors of the thesis will also incorporate their own thoughts based on the information about the subject presented in the thesis.

5.1 BIM Definition and Attitude

Based on the answers in both the questionnaire and the interviews, the main definition of BIM at CC is a 3D-model and aid in the daily work. This is very different from Goniakakis (2014) definition of BIM as an integrated process with a digital database. The answers reflect how they most commonly come in contact with the model, as a visualization tool and without much information. They do not yet have use of BIM to the full extent of its potential.

The respondents' limited definition of BIM is not seen as something negative in the thesis as the focus is on how BIM is used and their attitude towards it. BIM was in general seen as something positive for the production sites, even though not many aspects of it was implemented. The results from both the questionnaire and the interviews shows that there is a willingness to use BIM within production, since they have discovered some good uses, such as visualization and ease in communication. This was brought up in the study by Van Berlo and Natrop (2015), by being able to look in the model the communication was simplified and quicker. As Merschbrock and Nordahl-Rolfsen (2016) showed in their study, even workers have use of BIM, something that they could see at CC as well. However, at CC the worker use is only kept within installations, where many benefits were seen. By reducing the amount of rework and discussion time it is possible for them to make a better product. Some of the interviewees said that everything that makes sure that they do not have to redo work is good and should be used, since it reduces both construction time and the cost. This indicates that further worker use might become relevant in the future.

There is however a fear at the moment among the site management teams to let go of the 2D-drawings. The reason for holding back on moving entirely to BIM for many was that the BIM-model is not legally binding. Therefore, 2D-drawings have to be used, since they are controlled within the contract. There are however ways to work around the contract issue, showed in the Röfors bridge project (Malmkvist, 2018). If the model was incorporated into the contract in a similar way, most of the interviewees said that they would not oppose it, as long as they still had the opportunity to print out sections and parts on paper. Many felt that paper was easier to hand over to the workers than giving them a tablet. The site managers and supervisors were most reluctant to let go of the 2D-drawings. The site managers reason was that they are responsible for the construction being made according to the plans. To be certain they felt that they need the model in the contract to rely on it and that it is kept updated when changes happens. The supervisors on the other hand preferred the 2D-drawings since it was quicker to explain and draw on them, even though everyone understood the 3D-model easier and quicker. They thought however, that this will be solved when they get comfortable using the software.

5.2 Effects of BIM Implementation in Production

One of the positive effects of using BIM is that the preparation of documents and drawings can be done while the design of the project is in process, decreasing the time of a project (Lan et.al., 2015). This also brought up in the interviews. In some projects, based on the contract of it, the site management team worked parallel with the design of the project while in some others they started the construction of the building after the design phase. When there is a Design-Bid-Build (DBB) contract, the site management team is not a part of the design and consequently they cannot affect the model.

One more positive effect mentioned during the interviews and questionnaires is visualisation, one of the opportunities of BIM (see table 2), which makes understanding of the final product easier and finding possible errors before they occur. Azhar (2011) also pointed out that visualization is an important part of BIM, informing the stakeholders easier by showing the final product as well as the different stages it.

Furthermore, Azhar (2011) mentioned that using BIM in a project will lead to more accurate cost estimation and less time will be needed for the entire project. However, the results show that CC does not uses BIM for estimating the cost and time of a project. CC uses BIM mainly for only visualisation and collision control. Despite the fact that CC only uses some of the opportunities BIM provides, the site management teams communicate and collaborate better and reduce the occurrence of errors. Lindblad (2013) also refers that the use of BIM in a project reduces risks, the site management teams communicates and participates better something which leads to improvement of profitability and relationships and the reducing of the cost of the project. Nevertheless, some interviewees believe that a project costs more using BIM. This might be since they still work both with 2D-drawings and a BIM-model, meaning that the designers have to do double work. The lack of competence of BIM in both pre-production and production phase also makes the users spend more time in the software to design, find information and navigate.

A problem mentioned during the interviews was that BIM is not regulated in the contract. This leads to insecurities about who is responsible for the use of BIM. According to Azhar (2011), there is a lack of legislation regarding copyright issues of BIM and responsibility for risks through the use of BIM in construction industry. However, as seen in Malmkvist's report (2018), it is possible to include the BIM-model in the contract.

During the research, it was observed that the site management teams has limited knowledge and education about BIM. They are not experts and for this reason the company hires a BIM expert when there is a need. Enshassi et.al. (2016) also points out the lack of knowledge and Eastman et al. (2011) the lack of training of BIM and personal motivation of the project team as negative effects of using BIM in a project. These may increase the cost and time of a project as the project team, which is not familiar to BIM, may use unnecessary information and too detailed data. Also, the software used are not user-friendly and this is something which also found during the research. The interviewees stated that this is an issue since it takes a lot more time to understand the software. It might also mean that people with limited computer skills will avoid using BIM since they do not understand the software. CC should work on simplifying the software if they want a fast BIM implementation in the company.

In addition, the implementation of BIM becomes difficult because there are not specific standards which someone can follow, as well as a common platform for implementing BIM (Enshassi et al, 2016). This leads companies to create their own platform and standards in order to use BIM. Working in different software for the same project can be also an issue regarding compatibility (Chen et al., 2017). Dainty et al (2015) mention that a way to avoid this issue is to use IFC models which can be connected in a single model and they do not have any connection to the kind of software used to produce this single model. During the research for the thesis, the lack of specific standards and a common platform as well as the use of different software in a project noticed as some of the problems of using BIM. However, some of the interviewees mentioned that they use IFC models in their project in order to prevent these issues.

5.3 Company Support Systems

To succeed with BIM implementation in the construction process the senior management have to be involve (Epstein, 2012; Chan, 2014). At CC they have adopted a policy of implementing BIM in all projects above a target amount and due to its size, nearly every project has to use BIM in some way. This would indicate a top-down implementation plan. However, there seems to be a lack of support from the company and a lack of education of BIM within the site management teams and this speaks against top-down implementation. Based on the interviews and the questionnaire, the view from the people on site is more of a "slow and drawn out" implementation. As could be seen in table 5, some asked themselves why it has taken so long. The senior management does not seem to follow up on the decision made from the organization and the interviewees pointed out the lack of understanding from the senior management. Senior management take the decisions for the implementation of BIM, but they have not understood how much time someone needs to learn how to use BIM and that they need to spend money for this to succeed. BIM will not be used in a right way if it is not learned correctly and there are no instructions to follow. The site management teams need time and education as well as a mutual strategy from the company to succeed with BIM implementation. This means that the senior management should become more involved, show the benefits of BIM and follow up on how BIM implementation is going within the company.

Of our interviewees around half had gotten an education and among the respondents to the questionnaire barely 20% had received education, counting both internal and external. The lack of education might be the reason for the limited use of BIM on site. The site management team do not know what they need from a model regarding detail level and information in it, since they do not know what they can use it for. Therefore, they cannot communicate their demands to the pre-production and get a fully functional model. During the interviews, different ways to use BIM were mentioned. Some of the interviewees reacted with stating that they wanted to use those functions but, to be able, they needed more education. It was also noted that the respondents in the questionnaire that had received an education also wanted more education within the area, indicating that the education received was not enough to use BIM.

According to Chan's (2014) study the lack of training was the top barrier for implementation of BIM and this is what is lacking as well at CC. The research showed that the respondents which had an education in BIM in higher regard found it useful, since they now about more aspects than the 3D-model. There might be several reasons for why BIM education is missing within the company, one reason might be the cost. The construction industry is a low margin industry and therefore education for the employees is both a cost and time consuming, time that could have been spent working on a project. The cost of manufacturing the BIM-model was also mentioned as a reason for why it is not used. Another reason, brought up by the interviewees, is the time constraint. Many of the interviewees stated that they learn on site by themselves or with the aid of a co-worker. However, Azhar (2011) showed that BIM is an opportunity to save both money and time.

The regions in the studied company work independent from each other and therefore very differently. In the studied region, the level of BIM used in projects is very low and there is no support system. The question is then why this region have not worked in the same way as other regions and implemented a BIM group or having education for the different projects. As Chan (2014) showed in their research that there are some support systems to help the professionals with the implementation. Some of these was also brought up in the interviews and questionnaire results. At the studied region, some people experience a lot of talk about BIM, but no concrete action taken to get it out on site. Despite this, many of them have worked with BIM in some project. Chan (2014) stated that the most important support system for implementing BIM is "providing guidance on use of BIM", as mentioned in chapter 2.3. Strangely enough there are systems in place within the company, a BIM-manual to aid in the development of the model and other instructions. However, the site management teams seem to not know about these systems, especially the teams in construction. Some of them had no idea how to get a tablet, that would aid them in bringing the model out on site to the workers. Something that did not seem to be an issue for the people working in BAH. It seems that BAC can learn from BAH how to inform the site management teams about the existing support systems.

Another support system found in Chan's (2014) research was defining levels of BIM and providing training. The same wishes can be seen from the interviews and questionnaire that training is important for the implementation, the people on site need to be able to learn, and that with received training the interest in the usefulness of BIM increases. With this background and also that some systems are already in place in other parts of the company it seems like it would be possible to implement similar structures in the studied part of the organisation.

There are a lot of questions about the support from the company and also how long time it takes to implement BIM. The comments from the questionnaire show that the respondents think that CC, as a big company, should lead the exploration of BIM, something that they do not feel is happening. Dainty et al (2015) showed that the issue usually lies in the senior management and since a willingness from the site management teams is observed the issue with the implementation seems to lie with the senior management. This thesis will not discuss this further, but would like to see other studies looking into the willingness to implement BIM higher up in the organization structure.

6 CONCLUSION

The thesis is about BIM and how it is implemented in the studied construction company. After the presentation of the basic theoretical background about BIM and the collection of the necessary data, regarding the attitude, knowledge and needs of the site management teams in the studies company, using questionnaires and interviews, some very interesting results were taken. From the results, it is remarkable that the site management teams have enough knowledge on what BIM is and what it provides but lack of knowledge on how to use it. However, they are very positive and willing on using BIM in all phases of a project, but they feel unsure and not ready for that at the moment. They, as well as the workers, need to be more prepared and knowledgeable for this implementation starting using BIM not only in the office but also on site. They need to have an internal education on BIM and a functioning support system is necessary. They also feel that there is no one who is legally responsible about BIM implementation and for this reason contracts and legislation need updating.

BIM, through the different kind of properties which it has, gives the opportunity to the user to have a complete control of the project during its life-cycle. If the company used BIM in all phases of a building project then they could have better understanding of it and its elements, reducing misunderstandings and errors and, consequently, decreasing the time and cost of the project. In addition, continuing working with BIM in the production phase, the project team will have a complete virtual model of the building at the end of the project, something which may be very helpful when the model will be used in the future.

6.1 Answers to the Research Questions

What knowledge do the site management teams have about BIM?

Based on the research made using questionnaires and interviews some results regarding the knowledge of site management team about BIM have been obtained. The team has a satisfied knowledge on what BIM is and what they can do with this model but limited knowledge on know-how. While they know the opportunities that BIM provides they do not know how to use its functions in order to take advantage of these opportunities.

What are their attitudes towards BIM?

The findings regarding the attitude of site management teams towards BIM shows that the teams are very positive and willing to use BIM in all stages of a project. However, they still feel unsure and confused on how to use it. The use of BIM is done mainly by subcontractors. The site management team limits the use of BIM mainly in the office, not using it on site as well. They believe that workers should also have an access and be included on BIM for having a successful implementation. What is also important from the research results is that the site management teams do not have a clear view about who is responsible for BIM implementation and in case errors happen. Something which could be resolved if contracts and legislation were updated.

What is needed to help site management teams to implement BIM in production phase?

The results from the interviews and questionnaires show that the most important problems that the studied company encounters are the lack of knowledge regarding how to use BIM and the lack of support from a BIM expert in case someone needs help or cannot solve a problem. For these reasons, it is significant the site management teams to have an internal education on how to use BIM. In addition, a functioning support system is needed to provide instructions when someone needs help and to ensure the right flow of the process.

6.2 Suggestions for Improvement

Considering the literature review and the results of the questionnaires and interviews, some suggestions on how the studied organisation could improve the implementation of BIM in projects are provided below:

- Senior management should be involved to and drive the implementation of BIM in production spending time and money so that the implementation to be successful.
- Each employee should have enough time to learn the software. It may be better if they spend some hours in the office learning the software before using it in a project than learning some basics on BIM while they are working on the project.
- Creation of a support team that works with BIM implementation and will support the project team, giving solutions to questions about the program and its uses.
- Before implementation of BIM, the issues of responsibilities and warranties of BIM use should be identified, discussed and solved and every member of the project team should know which their responsibilities are in every phase of the project process.
- The site management teams should be informed better about the BIM guidelines which the company provides as well as the standardization of BIM process and guidelines, something to which BIM is lacking.

In summary the site management teams have good, but limited knowledge on how to use BIM, and they think that BIM is useful and need better support from the company. CC should therefore focus on creating a strategy, educating the site management teams and create a support function to successfully implement BIM at the construction sites.

6.3 Future Studies

The research done in the thesis showed some interesting results which may be used further and in different level. Some future research could be:

- the implementation of BIM in different regions at the studied organisation
- how BIM implementation is connected to the attitude of senior management
- what makes the different software not user-friendly and how this can be changed.

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APPENDIX

I: Interview

Presentation

- Presentation of us
- Explain the thesis
- Tell them that the interview will be anonymous
- Ask if it is okay to record the interview to transcribe the answers.
- Any questions before we start?
- Ask if it is alright to perform the interview in English, it is possible to answer questions in Swedish if needed
- Introductory questions
    - Name
    - Age
    - Educational background
    - Work background and current job

Questions

- What is your definition of BIM?
- What is your knowledge of BIM?
- Have you gotten any internal education of BIM and for how long?
    - What did the education contain?
    - Did the education really work? (Was the education useful to learn about BIM? Did education help you to learn about BIM? What BIM is, its use, how to use it.)
    - Would you like to have more education about BIM?
- Do you think BIM is useful or useless? Why?
- What do the company think about BIM?
- Have you been involved in a project using BIM or are you currently using BIM in your present project?
    - If yes,
        - How did you use BIM?
        - Which software did you use?
        - What kind of contract did you use in this project?
        - Who decides of using BIM generally in the project as well as in the production phase?
        - What changes were made from traditional production?
        - Did you replace any 2D-drawings with 3D in the production? Which and why? Would you have liked to?
        - What tools did you use in the production? (Computer, Ipad, screens, VR…)
        - Who had access to the model?
        - What was some positive/negative experiences from the project?
        - Do you want to use BIM again in other projects as well?

        - Did your attitude towards BIM change after using it?
        - What differences are there between project where BIM is implemented vs. not implemented? Have you noticed any changes since the implementation of BIM in production phase?
    - If no
        - Do you think any of your projects could have benefitted or been more complicated from BIM use?
        - What would you have needed/wanted to use BIM for in the project?
- What do you want to do with BIM?
- Which information do you want/need from BIM/a model?
    - Are there information that should be excluded?
    - Are there information that BIM does not provide?
- Is the model detailed enough or have to much details for its use?
    - If you exclude 2D-drawings, how much detail is needed?
        - Are you willing to use only BIM in all phases of a project?
- How do you communicate to other workgroups/colleagues what need to be done in a project? Could this be made easier by a 3D representation?
- Are there difficulties of understanding and communicating with other fields in the production?
- Are the workers involved to the use of BIM? How is your view at workers using BIM? Are they involved with BIM currently?
- What do you think is difficult with BIM? Where do you find difficulties using BIM?

II: Questionnaire

Avsnitt 1 av 7

BIM i produktion

Denna enkätundersökning är en del av ett examensarbete i masterprogrammet Design and Construction Project Management på Chalmers. Svaren kommer att användas för att skapa en uppfattning om platskontorens attityder och behov är när det gäller BIM implementering i produktionen.

Enkäten är anonym och inga åsikter som skrivs kommer att gå att knyta tillbaka till respondenterna. Genom att svara på enkäten ger du ditt tillstånd att vi använder datan i arbetet.

1. Kön *

- ◯ Kvinna
- ◯ Man
- ◯ Vill ej ange

2. Ålder (ex. 35) *

Kort svarstext

3. Ange högsta utbildningsnivå eller motsvarande *

- ◯ Grundskola
- ◯ Gymnasium
- ◯ Gymnasieingenjör
- ◯ Yrkeshögskola
- ◯ Högskola 3-årig
- ◯ Högskola 5-årig

4. Antal år i byggbranschen (ex. 7) *

Kort svarstext

5. Yrkestitel *

- Platschef
- Arbetsledare
- Entreprenadingenjör
- Annat ...

6. Är du bekant med BIM? (Building Information Modeling)

- Ja
- Nej
- Vet ej

7. Har du gått en internutbildning i BIM?

- Ja
- Nej
- Externutbildning

Efter avsnitt 1 Fortsätt till nästa avsnitt

Avsnitt 2 av 7

BIM-utbildning

Dessa frågor behandlar den utbildningen som du har gått.

7.1 Hur länge sedan var det du hade utbildningen?

- Under senaste året
- 1 år sedan
- 2 år sedan
- 3 år sedan
- 4 år eller längre sedan

7.2 Hur lång var utbildningen?

- 3-4 timmar
- 7-8 timmar
- 2-3 dagar
- 4-5 dagar
- Längre utbildning

7.3 Vad innehöll utbildningen? Flera svarsalternativ är möjliga

- Navigera i BIM-modellen
- Sortera bland byggnadsdelar och lager
- Ta ut information från modellen
- Produktionsplanering utifrån BIM
- Mängdning
- Ta ut mått
- Annat ...

7.4 Kände du att utbildningen innehöll det som behövdes?

- Ja
- Nej
- Kanske

7.5 Vad tyckte du om utbildningen?

	1	2	3	4	5	
Oanvändbar	○	○	○	○	○	Väldigt användbar

7.6 Kan du tänka dig att gå ytterligare utbildningar inom BIM?

- Ja
- Nej
- Kanske

7.7 Vad tycker du att en BIM utbildning ska innehålla? Flera svarsalternativ är möjliga

- [ ] Navigera i BIM-modellen
- [ ] Sortera bland byggnadsdelar och lager
- [ ] Ta ut information från modellen
- [ ] Produktionsplanering utifrån BIM
- [ ] Mängdning
- [ ] Ta ut mått
- [ ] Annat ...

Efter avsnitt 2 **Öppna avsnitt 4 (BIM i produktion)**

Avsnitt 3 av 7

BIM-utbildning

Dessa frågor undersöker vad du vill ha ut av en utbildning inom BIM.

7.a Vill du gå en utbildning i BIM?

- ○ Ja
- ○ Nej
- ○ Kanske

7.b Vad vill du att en BIM-utbildning ska innehålla? Flera svarsalternativ är möjliga

- [ ] Navigera i BIM-modellen
- [ ] Sortera bland byggnadsdelar och lager
- [ ] Ta ut information från modellen
- [ ] Produktionsplanering utifrån BIM
- [ ] Mängdning
- [ ] Ta ut mått
- [ ] Annat ...

Efter avsnitt 3 **Fortsätt till nästa avsnitt**

Avsnitt 4 av 7

BIM i produktion

Dessa frågor undersöker vad du har för kunskaper om BIM.

8. Känner du att du har tillräckligt med kunskaper för att kunna använda BIM?

- Ja
- Nej
- Vet ej

9. Vad tycker du om BIM?

	1	2	3	4	5	
Väldigt dåligt	○	○	○	○	○	Väldigt bra

10. Har du arbetat med BIM i ett projekt? *

- Ja
- Nej

Efter avsnitt 4 **Fortsätt till nästa avsnitt**

Avsnitt 5 av 7

Nuvarande BIM-användning i produktion

Dessa frågor är för att undersöka hur BIM-användningen fungerar idag.

10.1 Ändrade att arbeta med BIM din uppfattning om det?

	1	2	3	4	5	
Till det sämre	○	○	○	○	○	Till det bättre

10.2 Vilka verktyg HAR du använt vid BIM-användning? Flera svarsalternativ är möjliga

- [ ] Dator
- [ ] Telefon
- [ ] Smartboard
- [ ] Touchscreen
- [ ] Skärm (större skärm i möteslokal eller projektor)
- [ ] Ipad eller surfplatta
- [ ] VR-glasögon
- [ ] BIM-station uppställd på arbetsplatsen
- [ ] Annat ...

10.3 Vilka programvaror har du använt vid BIM-användning och hur nöjd är du med programvaran? Betygsätt från missnöjd (1) till mycket nöjd (5).

	1	2	3	4	5	Har ej använt
Tekla BIMsight	○	○	○	○	○	○
Solibri Model ...	○	○	○	○	○	○
Vico Software	○	○	○	○	○	○
Navisworks	○	○	○	○	○	○
Revit-viewer	○	○	○	○	○	○
Revit	○	○	○	○	○	○
SketchUp	○	○	○	○	○	○
ArchiCad	○	○	○	○	○	○
Annat	○	○	○	○	○	○

Om annat, vilken programvara?

Kort svarstext

10.4 Hur användarvänligt tycker du att BIM är i följande fall. Betygsätt från svår använt (1) till lätt använt (5).

	1	2	3	4	5	Ingen uppfatt...
Planering (av...	○	○	○	○	○	○
Arbetsberedni...	○	○	○	○	○	○
Mängdning (ta...	○	○	○	○	○	○
Virtual Reality	○	○	○	○	○	○
Mobilitet (att k...	○	○	○	○	○	○
Hitta informati...	○	○	○	○	○	○
Mäta (ta fram ...	○	○	○	○	○	○
Annat använd...	○	○	○	○	○	○

Om annat användningsområde, vilket?

Lång svarstext

10.5 Hur använde sig medarbetarna av BIM-modellen? Flera svarsalternativ är möjliga

	Använde information (ex. t...	Endast tittade i modellen	Ingen tillgång
Platschef	☐	☐	☐
Arbetsledare	☐	☐	☐
Entreprenadingenjör	☐	☐	☐
Snickare	☐	☐	☐
Elektriker	☐	☐	☐
Rörläggare	☐	☐	☐
Sprinkler	☐	☐	☐
Ventilation	☐	☐	☐
Grundläggare	☐	☐	☐
Annan arbetsgrupp	☐	☐	☐

Om annan arbetsgrupp, vilken?

Kort svarstext

10.7 Vad HAR du använt BIM till i produktionen? Flera svarsalternativ är möjliga

	Har använt	Har ej använt
APD-plan	○	○
4D-simulering (modellen kombineras ...	○	○
Planering	○	○
Mängdning	○	○
Mätning	○	○
Ritningar	○	○
3D-modell	○	○
Arbetsberedning	○	○
Säkerhetsplanering	○	○
Fas planering	○	○
VR (virtual reality)	○	○
AR (augmented reality)	○	○
Annat användningsområde	○	○

Om annat användningsområde, vilket?

Kort svarstext

Efter avsnitt 5 **Fortsätt till nästa avsnitt**

Avsnitt 6 av 7

Framtida BIM-användning inom produktionen

Dessa frågor behandlar om hur du tycker att BIM-användingen ska utvecklas.

11. I vilken fas/vilka faser anser du att BIM är användbart? Flera svarsalternativ är möjliga

- [ ] Marknad
- [ ] Kalkyl och anbud
- [ ] Produktionsförberedelser
- [ ] Produktion
- [ ] Garanti
- [ ] Alla faser
- [ ] Inga faser

12. Vad VILL du kunna använda BIM till i produktionen? Flera svarsalternativ är möjliga

	Vill använda	Vill ej använda
APD-plan	○	○
4D-simulering (modellen kombineras ...	○	○
Planering	○	○
Mängdning	○	○
Mäta	○	○
Ritningar	○	○
3D-modell	○	○
Arbetsberedning	○	○
Säkerhetsplanering	○	○
Fas planering	○	○
VR (virtual reality)	○	○
AR (augmented reality)	○	○
Annat användningsområde	○	○

Om annat användningsområde, vilket?

Kort svarstext

13. Vilka verktyg VILL du använda i BIM-användning? Flera svarsalternativ är möjliga

- [ ] Dator
- [ ] Telefon
- [ ] Smartboard
- [ ] Touchscreen
- [ ] Skärm (större skärm i möteslokal eller projektor)
- [ ] Ipad eller surfplatta
- [ ] VR-glasögon
- [ ] BIM-station uppställd på arbetsplatsen
- [ ] Annat ...

14. Vad är BIM för dig? Flera svarsalternativ är möjliga

- [ ] 3D-modell
- [ ] Programvara
- [ ] Informationsdatabas över byggnaden
- [ ] En arbetsprocess
- [ ] Ett arbetsverktyg
- [ ] Kommunikationsmedel
- [ ] Visualiseringsverktyg
- [ ] Annat ...

Efter avsnitt 6 **Fortsätt till nästa avsnitt**

Avsnitt 7 av 7

Egen reflektion

Beskrivning (valfritt)

15. Hur användbart anser du att BIM är ute i produktion?

	1	2	3	4	5	
Oanvändbart	○	○	○	○	○	Väldigt användbart

16. Har du något att tillägga angående BIM och digitaliseringen i produktionen?

Lång svarstext

III: Thematic analysis mind-map

The thematic mind-map presented in the four themes branches with subthemes in. Presented in order as follows:

- Control mechanisms of construction
- BIM awareness and appreciation
- On site usage
- Digital environment

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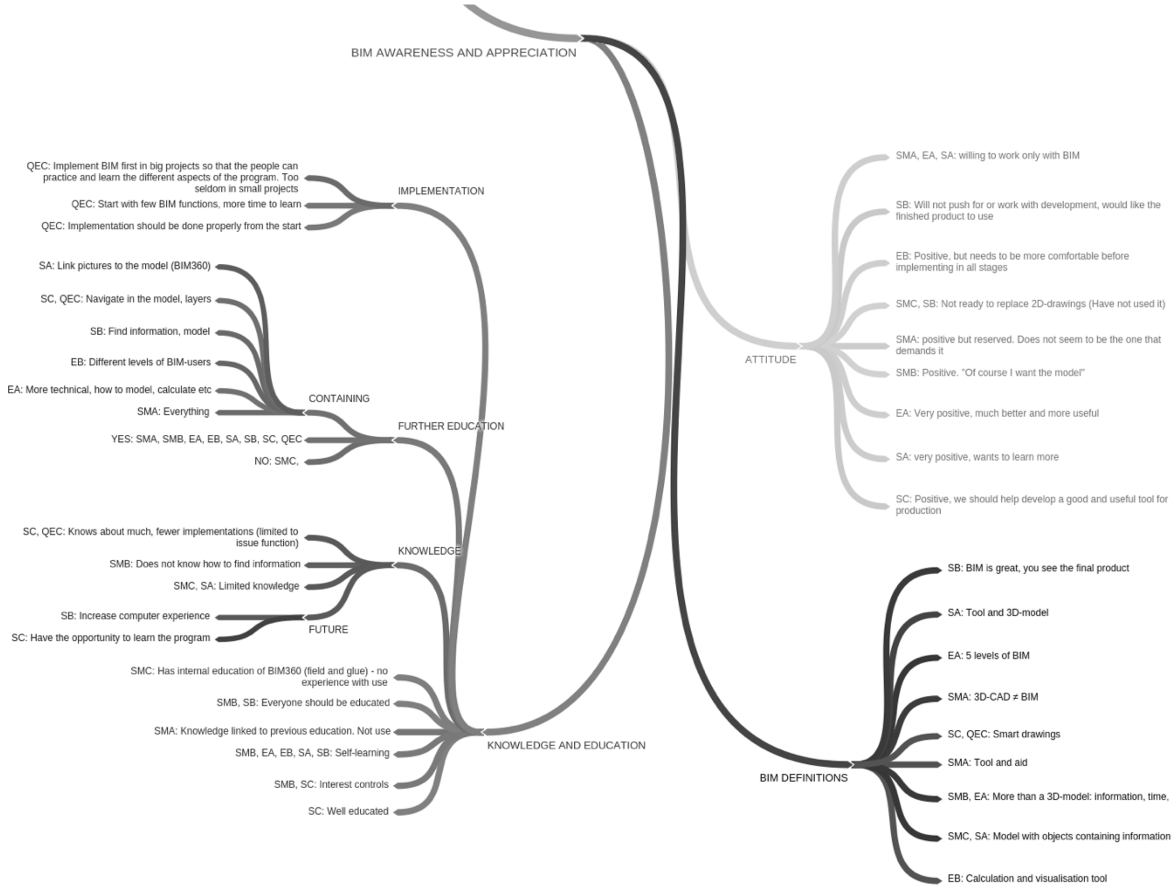
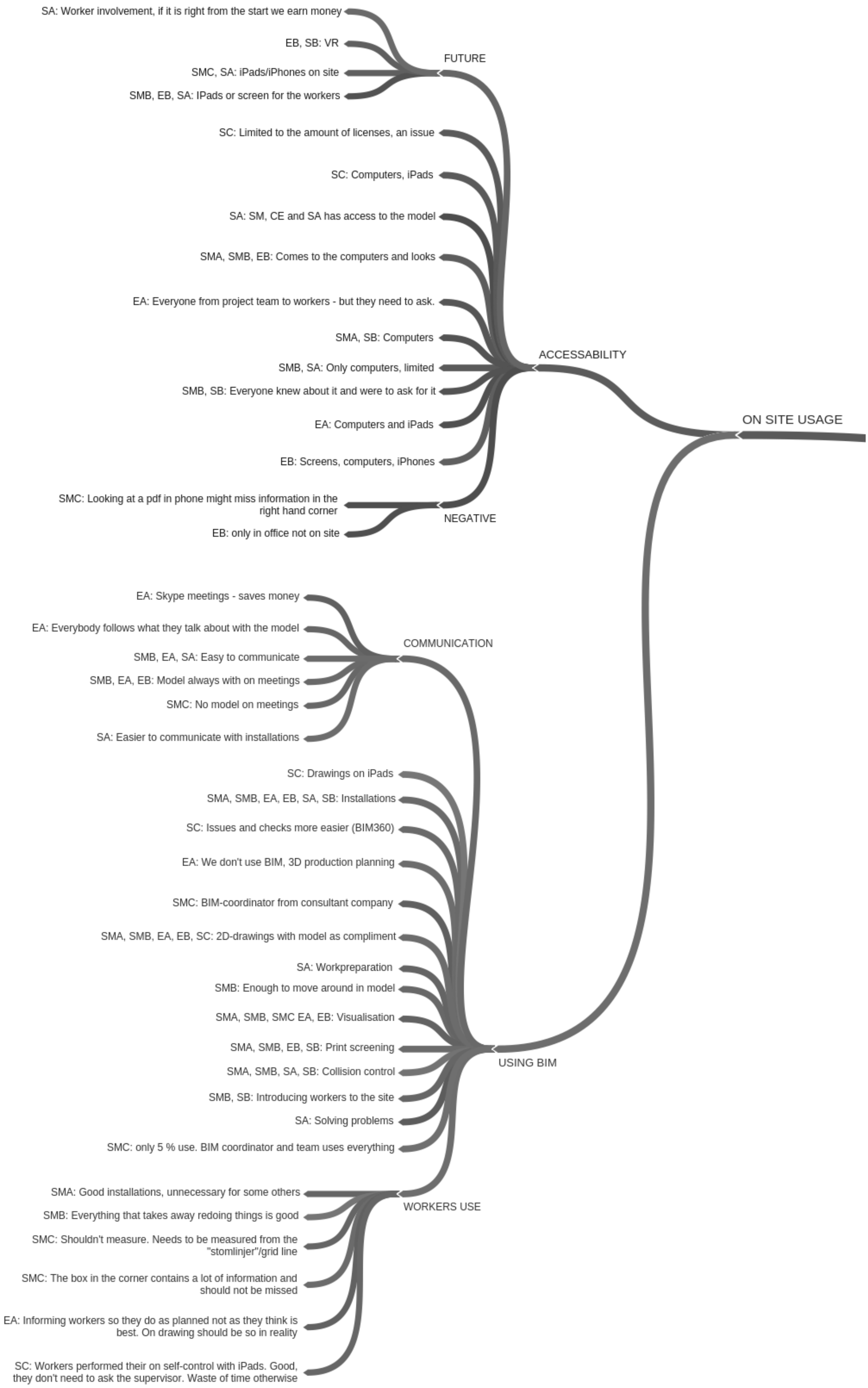
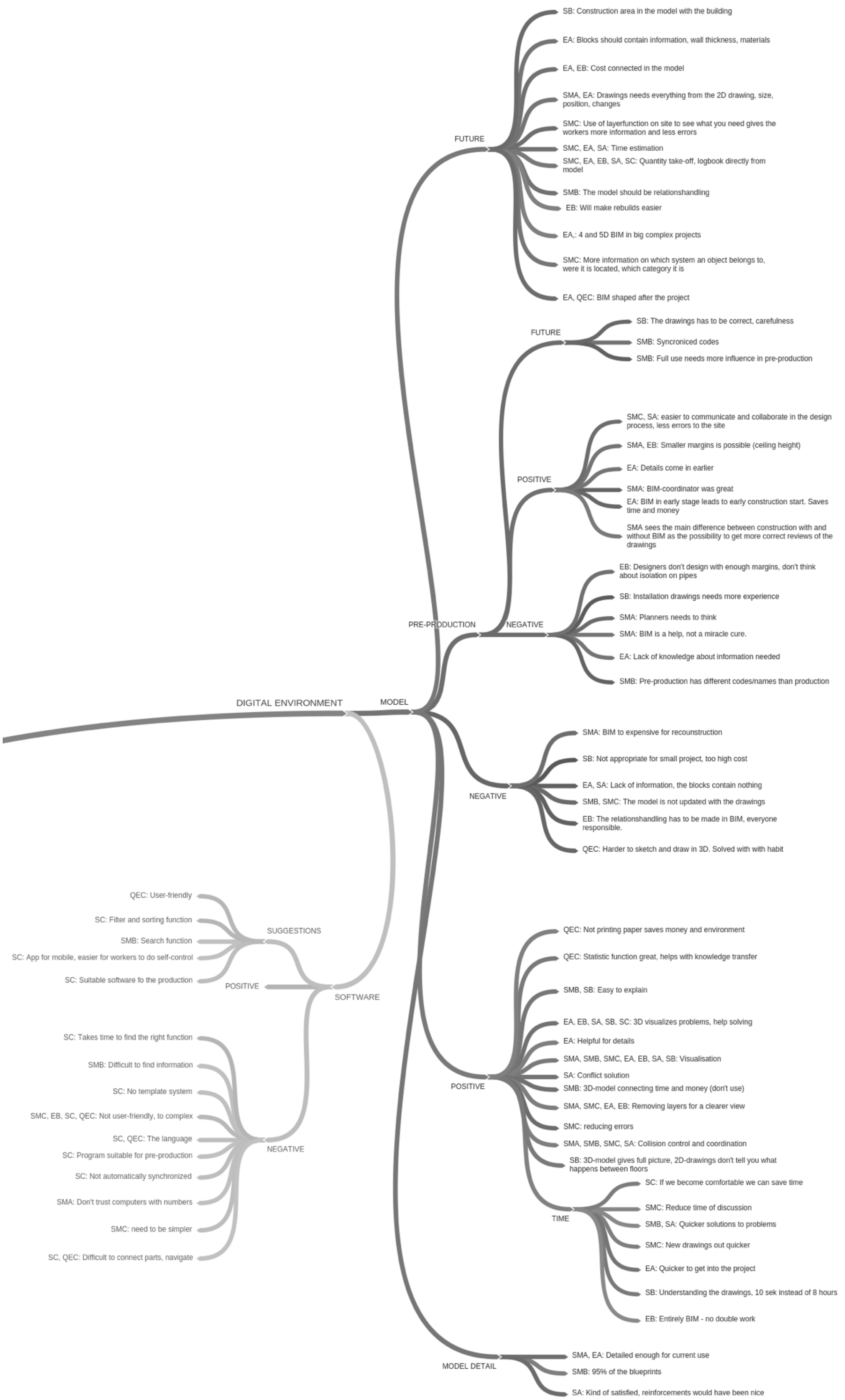

BIM AWARENESS AND APPRECIATION
IMPLEMENTATION
QEC: Implement BIM first in big projects so that the people can practice and learn the different aspects of the program. Too seldom in small projects
QEC: Start with few BIM functions, more time to learn
QEC: Implementation should be done properly from the start
CONTAINING
SA: Link pictures to the model (BIM360)
SC, QEC: Navigate in the model, layers
SB: Find information, model
EB: Different levels of BIM-users
EA: More technical, how to model, calculate etc
SMA: Everything
FURTHER EDUCATION
YES: SMA, SMB, EA, EB, SA, SB, SC, QEC
NO: SMC,
KNOWLEDGE
SC, QEC: Knows about much, fewer implementations (limited to issue function)
SMB: Does not know how to find information
SMC, SA: Limited knowledge
FUTURE
SB: Increase computer experience
SC: Have the opportunity to learn the program
KNOWLEDGE AND EDUCATION
SMC: Has internal education of BIM360 (field and glue) - no experience with use
SMB, SB: Everyone should be educated
SMA: Knowledge linked to previous education. Not use
SMB, EA, EB, SA, SB: Self-learning
SMB, SC: Interest controls
SC: Well educated
ATTITUDE
SMA, EA, SA: willing to work only with BIM
SB: Will not push for or work with development, would like the finished product to use
EB: Positive, but needs to be more comfortable before implementing in all stages
SMC, SB: Not ready to replace 2D-drawings (Have not used it)
SMA: positive but reserved. Does not seem to be the one that demands it
SMB: Positive. "Of course I want the model"
EA: Very positive, much better and more useful
SA: very positive, wants to learn more
SC: Positive, we should help develop a good and useful tool for production
BIM DEFINITIONS
SB: BIM is great, you see the final product
SA: Tool and 3D-model
EA: 5 levels of BIM
SMA: 3D-CAD ≠ BIM
SC, QEC: Smart drawings
SMA: Tool and aid
SMB, EA: More than a 3D-model: information, time,
SMC, SA: Model with objects containing information
EB: Calculation and visualisation tool


ON SITE USAGE
ACCESSABILITY
FUTURE
SA: Worker involvement, if it is right from the start we earn money
EB, SB: VR
SMC, SA: iPads/iPhones on site
SMB, EB, SA: IPads or screen for the workers
SC: Limited to the amount of licenses, an issue
SC: Computers, iPads
SA: SM, CE and SA has access to the model
SMA, SMB, EB: Comes to the computers and looks
EA: Everyone from project team to workers - but they need to ask.
SMA, SB: Computers
SMB, SA: Only computers, limited
SMB, SB: Everyone knew about it and were to ask for it
EA: Computers and iPads
EB: Screens, computers, iPhones
NEGATIVE
SMC: Looking at a pdf in phone might miss information in the right hand corner
EB: only in office not on site
USING BIM
COMMUNICATION
EA: Skype meetings - saves money
EA: Everybody follows what they talk about with the model
SMB, EA, SA: Easy to communicate
SMB, EA, EB: Model always with on meetings
SMC: No model on meetings
SA: Easier to communicate with installations
SC: Drawings on iPads
SMA, SMB, EA, EB, SA, SB: Installations
SC: Issues and checks more easier (BIM360)
EA: We don't use BIM, 3D production planning
SMC: BIM-coordinator from consultant company
SMA, SMB, EA, EB, SC: 2D-drawings with model as compliment
SA: Workpreparation
SMB: Enough to move around in model
SMA, SMB, SMC EA, EB: Visualisation
SMA, SMB, EB, SB: Print screening
SMA, SMB, SA, SB: Collision control
SMB, SB: Introducing workers to the site
SA: Solving problems
SMC: only 5 % use. BIM coordinator and team uses everything
WORKERS USE
SMA: Good installations, unnecessary for some others
SMB: Everything that takes away redoing things is good
SMC: Shouldn't measure. Needs to be measured from the "stomlinjer"/grid line
SMC: The box in the corner contains a lot of information and should not be missed
EA: Informing workers so they do as planned not as they think is best. On drawing should be so in reality
SC: Workers performed their on self-control with iPads. Good, they don't need to ask the supervisor. Waste of time otherwise


DIGITAL ENVIRONMENT
MODEL
FUTURE
SB: Construction area in the model with the building
EA: Blocks should contain information, wall thickness, materials
EA, EB: Cost connected in the model
SMA, EA: Drawings needs everything from the 2D drawing, size, position, changes
SMC: Use of layerfunction on site to see what you need gives the workers more information and less errors
SMC, EA, SA: Time estimation
SMC, EA, EB, SA, SC: Quantity take-off, logbook directly from model
SMB: The model should be relationshandling
EB: Will make rebuilds easier
EA,: 4 and 5D BIM in big complex projects
SMC: More information on which system an object belongs to, were it is located, which category it is
EA, QEC: BIM shaped after the project
PRE-PRODUCTION
FUTURE
SB: The drawings has to be correct, carefulness
SMB: Syncroniced codes
SMB: Full use needs more influence in pre-production
POSITIVE
SMC, SA: easier to communicate and collaborate in the design process, less errors to the site
SMA, EB: Smaller margins is possible (ceiling height)
EA: Details come in earlier
SMA: BIM-coordinator was great
EA: BIM in early stage leads to early construction start. Saves time and money
SMA sees the main difference between construction with and without BIM as the possibility to get more correct reviews of the drawings
NEGATIVE
EB: Designers don't design with enough margins, don't think about isolation on pipes
SB: Installation drawings needs more experience
SMA: Planners needs to think
SMA: BIM is a help, not a miracle cure.
EA: Lack of knowledge about information needed
SMB: Pre-production has different codes/names than production
NEGATIVE
SMA: BIM to expensive for recounstruction
SB: Not appropriate for small project, too high cost
EA, SA: Lack of information, the blocks contain nothing
SMB, SMC: The model is not updated with the drawings
EB: The relationshandling has to be made in BIM, everyone responsible.
QEC: Harder to sketch and draw in 3D. Solved with with habit
POSITIVE
QEC: Not printing paper saves money and environment
QEC: Statistic function great, helps with knowledge transfer
SMB, SB: Easy to explain
EA, EB, SA, SB, SC: 3D visualizes problems, help solving
EA: Helpful for details
SMA, SMB, SMC, EA, EB, SA, SB: Visualisation
SA: Conflict solution
SMB: 3D-model connecting time and money (don't use)
SMA, SMC, EA, EB: Removing layers for a clearer view
SMC: reducing errors
SMA, SMB, SMC, SA: Collision control and coordination
SB: 3D-model gives full picture, 2D-drawings don't tell you what happens between floors
TIME
SC: If we become comfortable we can save time
SMC: Reduce time of discussion
SMB, SA: Quicker solutions to problems
SMC: New drawings out quicker
EA: Quicker to get into the project
SB: Understanding the drawings, 10 sek instead of 8 hours
EB: Entirely BIM - no double work
MODEL DETAIL
SMA, EA: Detailed enough for current use
SMB: 95% of the blueprints
SA: Kind of satisfied, reinforcements would have been nice
SOFTWARE
SUGGESTIONS
QEC: User-friendly
SC: Filter and sorting function
SMB: Search function
SC: App for mobile, easier for workers to do self-control
SC: Suitable software fo the production
POSITIVE
NEGATIVE
SC: Takes time to find the right function
SMB: Difficult to find information
SC: No template system
SMC, EB, SC, QEC: Not user-friendly, to complex
SC, QEC: The language
SC: Program suitable for pre-production
SC: Not automatically synchronized
SMA: Don't trust computers with numbers
SMC: need to be simpler
SC, QEC: Difficult to connect parts, navigate

IV: Comments in Swedish

- *Skall detta ut i "verkligheten" så skall det vara så användarvänligt det bara går. Alla är inte så hemma i datorns värld så det skall verkligen vara så enkelt det bara går att använda.*
- *Tror det kommer vara ett superbra verktyg när alla kan använda det och vill använda det.*
- *Tror på BIM lika bra att följa framtiden från början.*
- *Detta borde finnas mer i projekteringen/produktionen även för mindre projekt. Ett problem som finns är att Systemhandling mm tar fram i 2-D istället för 3-D och det sedan ses som en kostnad att ta fram 3-D för fortsatt projektering.*
- *Svagaste länken är alla våra UE som utför merparten av produktionen*
- *Min egna åsikt är att applikationen är för komplex i dagsläget för att kunna användas i all delar. Implementeringen bör begränsas till några få områden för att sedan successivt ökas.*
- *När kommer det igång? Har hört i 6 år att BIM är en revolution för byggmarknaden men har ännu inte sett det användas ute i produktion. Ännu skriver man ut ritningar och mäter med linjal. Vad är problemet, varför används det inte?*
- *För att kunna använda det fullt ut krävs en omfattande utbildning i skolbänken.*
- *Bra i vissa projekt som nyproduktion, dock överkurs i renoveringar*
- *Det borde gå snabbare, vi ligger efter!*
- *Ska vara mer tillgängligt. En telefon eller något som man alltid har med sig.*
- *Vet ej hur "bra" bim är då jag aldrig jobbat med detta*
- *Jag tycker att vi ligger alldeles för efter med digitaliseringen och därför började vi använda BIM360 till arbetsberedningar, egenkontroller, besiktningar och skyddsronder. Vi på CC borde vara en av de ledande företagen i digitaliseringen men känns som vi inte kommit någon vart än.*
- *Äldre personer har oftast ingen förmåga att använda BIM, vilket kräver mycket arbete av yngre (ofta nya arbetsledare?) då mycket information finns att ta fram bara man vet hur. Blir besvärligt om det blir så mycket tid att lägga på att hjälpa andra navigera i modeller att man behöver börja ta betalt för det.*
- *Jag anser att det krävs väldigt tydlig information till byggena vad det kan användas till och hur det används och att det trycks på med kraft från ledning eller liknande så att det implementeras snabbt*