CHALMERS
UNIVERSITY OF TECHNOLOGY

BIM use in production

The use of BIM in a Swedish construction company

Master's thesis in Design and Construction Project Management

Daniel Blomberg

Department of Architecture and Civil Engineering
Division of Construction Management
Research Group Name
CHALMERS UNIVERSITY OF TECHNOLOGY
Master's Thesis ACEX30-19-40
Gothenburg, Sweden 2019

MASTER'S THESIS ACEX30-19-40

BIM use in production

The use of BIM in a Swedish construction company

Master's Thesis in Design and Construction Project Management

Daniel Blomberg

Department of Architecture and Civil Engineering
Division of Construction Management
CHALMERS UNIVERSITY OF TECHNOLOGY
Göteborg, Sweden 2019

BIM use in production
The use of BIM in a Swedish construction company

Master's Thesis in Design and Construction Project Management

Daniel Blomberg

Examensarbete ACEX30-19-40
Institutionen för arkitektur och samhällsbyggnadsteknik
Chalmers tekniska högskola, 2019

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

Department of Architecture and Civil Engineering
Göteborg, Sweden, 2019

BIM use in production

The use of BIM in a Swedish construction company

Master's thesis in Design and Construction Management

Daniel Blomberg

Department of Architecture and Civil Engineering
Division of Construction Management
Chalmers University of Technology

ABSTRACT

The use of building information modeling, BIM, has been active in the design phase of construction and benefits have been found while studying the use in facility management. However, the use and benefits have been less exploited during the construction phase. This thesis studies the use of BIM within a Swedish construction company during the construction phase. The results for the thesis have been collected through several site visits, conducting interviews for qualitative results, and the responses on a survey to receive quantitative results. The results indicated a positivity towards BIM and the will to learn more within the area. The company started an incentive with *digital leaders*, dedicated employees on-site with a digital responsibility, during the thesis. The incentive of having *digital leaders* in production is great, both from the authors perspective and the interviewees. With a dedicated person on site corporate information can be transmitted easier as well as support to users. The greatest benefit of using BIM on the construction site was how it made understanding the buildings and construction process easier, it also ensured that all participants interpreted the building in the same way. As visualization in 3D enable an easier process of understanding than regular 2D drawings. There were also findings indicating a power shift due to easier understanding of the construction with the help of BIM.

Keywords: BIM on site, BIM use in construction, visualization, power change.

BIM användande inom produktion

Använandet av BIM i ett svenskt konstruktions företag

Examensarbete inom masterprogrammet Design and Construction Project Management

Daniel Blomberg

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

SAMMANFATTNING

Användandet av BIM har existerat i design fasen av byggprojekt och nyttor med BIM har funnits i fastighetsskötsel inom eftermarknad. Dock har lite forskning gjorts på dess påverkan under konstruktionsfasen av byggprojekt. Denna examensuppsats fokuserar på användandet av BIM under byggfasen i ett svenskt byggföretag. Detta har genomförts genom flertalet arbetsplatsbesök med intervjuer och en enkät. Detta har medfört att både kvalitativa och kvantitativa resultat har hittats. Resultaten har indikerat en positivitet till BIM och en vilja att lära sig mer inom området. Företaget startade upp ett initiativ med digitala ledare, arbetare med ett digitalt ansvar på arbetsplatsen, under examensarbetestiden. Initiativet att implementera digitala ledare inom byggproduktionen är positiv, både från författarens perspektiv så väl som de intervjuade. Med en dedikerad person på arbetsplatsen kan företagsinformation bli kommunicerat lättare och bistå med support till de andra på arbetsplatsen. Den största fördelen med BIM på byggarbetsplatsen var hur den underlättade förståelsen av byggnaden och byggprocessen, den säkerhetsställde också att alla tolkade byggnaden på samma sätt. Detta för att visualisering i 3D underlättar förståelsen jämfört med vanliga 2D ritningar. Det upptäcktes också resultat som indikerade ett maktskifte på grund av underlättningen av förståelse med hjälp av BIM.

Nyckelord: BIM på arbetsplatsen, BIM användande inom konstruktion, visualisering, maktskifte

Contents

Chart list

Figure list

Table list

List of abbrevations

BIM – Building information model
BIM – Building information modelling
IFC – Industry Foundation Classes
RFI – request for information
ITO – Information take-off
LOD – Level of Development
MEP – Mechanical, Electrical and Plumbing

Preface

This thesis could not have been written without the help from several people. I would therefore like to extend my greatest thanks to the people involved with making this thesis possible.

- ❖ Mikael Johansson, my supervisor at Chalmers for the help with questions and ideas for the thesis.
- ❖ Martin Gustavsson, Joel Öman and Daniel Öhrstig, and all others at the construction company for making this thesis possible.
- ❖ The interviewees that took time out of their hectic day to answer my questions. Whom without this thesis would not be possible.
- ❖ All respondents on the survey whom with their answers enabled a greater result for the thesis.
- ❖ My student opponents for helping me with a fresh pair of eyes to make the thesis better.

Thank you!

Daniel Blomberg

1 Introduction

BIM or Building Information Model, was introduced almost fifteen years ago and has been branded to be the solution to reduce waste and inefficiency in the construction industry (Chelson, 2010). The construction industry has seen an increase of only 1% in productivity for the last 20 years (EU BIM Task Group, 2017). It is estimated that 10% - 20% of construction expenses can be saved with digitalized engineering. However, one could argue that the use of BIM has not come as far as expected during these fifteen years since many organizations have taken a careful approach due to insufficient data, regarding the profitability of using BIM. The adoption rate of BIM use in the construction industry has been lower than estimated, the reasons behind this are hard to identify, since the reasons seem to change from project to project (Walasek & Barszcz, 2017). The concept of BIM is beneficial throughout the entire life-cycle of a building (Englund & Grönlund, 2018). However, the costs are instant and placed at the start of the project. These initial costs prevent the adoption of BIM, since it is tough to see the long-term benefits.

The research focus with BIM has been directed towards the use in facility management and pre-construction design, and a lot of research has been made on it. However, the use of BIM within production is less covered (van Berlo & Natrop, 2014). Productivity increases in projects when BIM is used. Depending on how the BIM process is managed, gains of 5% - 40% have been observed (Chelson, 2010). People who have used BIM in a project are often satisfied and wish to continue working with the tools. Solibri Model Checker is one tool to help implement BIM work on the production site. According to Solibri, they argue that BIM helps with design decisions, document production, planning, performance predictions and cost-estimates (Solibri Inc, 2018).

This thesis researches a construction company in Sweden, which has experience from using BIM on different levels in different projects for several years. However, the use has mainly been for pre-construction planning.

1.1 Aim and Outcome

The aim of this thesis is to take a deeper look into how BIM can be used to improve on-site production in the researched construction company. The results of the thesis will hopefully help the construction company in decision making regarding BIM in production.

1.2 Research Questions

The thesis will focus on the following questions:

- What are the main purposes of using BIM in production?
- How is BIM used by the site personnel today, and what do they want to use it for in the future?
- What knowledge is needed for BIM to be beneficial in production?
- What are the superior users using BIM for compared to the rest?

1.3 Scope and limitations

In this thesis, it is decided that the focus will lie on how to use BIM during the construction phase in the studied construction company. It has been restricted to investigate mainly one region in the construction company. Therefore, this will regard all tasks occurring on the construction site and the construction site office. Facility management and selling purposes will not be considered. Planning at the earlier stages of the project will be excluded, but planning through meetings that happen on-site will be taken into consideration.

The thesis scope is to investigate the use of the model on site in the researched company. It will take into consideration the site-personnel use of the BIM in their everyday work in order to plan, structure and evaluate the projects. In this thesis, the craftsman´s use of the software will not be taken into consideration.

1.4 Structure of the Thesis

This thesis follows the following structure.

- Chapter 2: Theoretical background grounded in a literature study is presented. Within the chapter BIM is explained further, benefits, drawbacks and implementation at the construction site.
- Chapter 3: In this chapter the method used to conduct the thesis is presented.
- Chapter 4: Results and analysis of the conducted interviews and survey is presented and analyzed. There is also information presented of internal documents considering BIM in the studied company.
- Chapter 5: The results and theory is discussed to gain further insight. In this chapter some of the authors own thoughts are affecting the text as well.
- Chapter 6: Contains a brief conclusion of the research and answers on the research questions. Also some thoughts on future research ideas are presented.

2 Theoretical Background

One of the reasons why BIM was introduced in the construction industry was the growing problem with visualizing the entire projects, as complexities have been increasing (Chelson, 2010). With BIM, information can be stored in one place, enabling a greater screening process and collaboration between professions. Working with BIM forces the project team to put more effort into early building design, resulting in an overall shorter project time.

Changes only happen in organizations or industries when they find the change beneficial compared to the current solution (Merschbrock & Nordahl-Rolfsen, 2016). Therefore, for BIM to advance more in the construction industry it is important to show what advantages it has compared to current solutions. After reaching a 16% adoption rate for innovation, the incentive for people to use it due to scientific excitement is reached (Love & Wang, 2012). The limit of this incentive is reached, as 18% of construction managers use BIM in their everyday work. Thus, a change in strategy and marketing need to be done, often leaning towards providing evidence of success in society (Walasek & Barszcz, 2017). The usefulness and enhancement of ones work with the help of the new technology is important regarding if the affected person is willing to learn and use it (Merschbrock & Nordahl-Rolfsen, 2016). In a study made by Brantisa and Norberg (2018), they found that 87% of the participants wanted more education within BIM usage, anticipating a positive view of BIM in the construction industry.

Areno (2018) resembles the change process of implementing BIM in construction to learn how to swim. First learn the basics, legs and arms separately, then combining them to stay floating without help. You must trick kids into trying, since it is scary to be out of control in the water. This need does also exist within organizations trying to change. The old safe way and the new risky way, without control. However, we do not need to learn how to swim but teach ourselves a new stroke. Therefore, one needs to understand the benefits of learning the new stroke instead of staying afloat with the initial one.

Chelson (2010) implies from his studies that the contractor should be the ones responsible for modeling, as they have the most responsibility regarding collaboration. Interrupted workflows, due to better planning, and re-work can be minimized with the use of BIM (Malmkvist, 2013). On a construction site, only the built material adds value to the finished product. Thus, the work managing workers, reporting and evaluating are none-value adding processes (Chelson, 2010). Trying to minimize the effort and time consumed doing these tasks would benefit the production.

BIM can be categorized into different categories depending on the level of information they include (Malmkvist, 2013). 3D includes the model that visualize

geometry and attributes. If a time-factor is added to the BIM, it becomes 4D. The inclusion of prices and costs makes it 5D. Hesselgard (2018) even describes 6D, implementing environmental data, and 7D with the inclusion of facility management. The BIM can include as much information as the creator determines (Malmkvist, 2013). The BIM creates what the construction industry has lacked in history, the ability to produce prototypes before constructing. This makes it possible to do different iterations of the model, evaluating different aspects, to make the finished product as good as possible. However, more information contained within the model is not always better (Chelson, 2010). Too much information might cluster up the model hiding other, more vital, information. Deciding what information goes into the model is vital for the productivity to rise, and costs to decrease.

2.1 Definition of BIM

BIM can be regarded as a technological tool. However, it is important to understand that BIM is rather a process than a tool (Chelson, 2010). The BIM process regards and initiates collaboration. There are different levels of BIM use. Starting with only producing the BIM for your own enjoyment, continuing to collaborate models and finishing with using the BIM as a contract binding document. Chelson (2010) described characteristics of what a true BIM application should have:

- Digital
- Spatial (3D)
- Measurable (quantity, dimensions, and query)
- Comprehensive (comprehend and communicate the design, building performances, constructability, and include sequential and financial aspects of means and methods)
- Accessible by all (cloud-based, IFC-file format)
- Durable (useful throughout all different construction phases)

2.2 Level of Development

A universal standard regarding the detail of BIM is named Level of Development, as described in the AIA E202 LOD specification guide (BIMForum, 2017). Considering the Level of Development, LOD, presented by AIA E202 all higher levels need to have all the required information from the previous levels. For instance, a BIM cannot be off LOD 300 standard without checking off the requirements for LOD 200.

Table 1 - Explanation of Level of Development. (Adpated from BIMForum 2017)

LOD	Description	Usefulness	Example (Light fixture)
100	The elements are not geometric representations. Information is attached to the model but without the correct size, placement or shape.	Measurements cannot be derived as they are considered approximate.	Cost / m^2 and attachment to floor / slabs.
200	Objects can be considered placeholders. These may be objects recognizable to the real product, or just volumes that occupy space.	Measurements cannot be derived from the model, as objects are only placeholders.	ight fixture, a generic approximate placement, and size.
300	The BIM is containing information about the quantity, size, shape, location, and orientation of the objects. The project origin is located and objects are placed in consideration of this.	Measurements and information can be obtained from the model, without using non-modeled information	Design specified 2X4 light fixture. Specific size, shape, and placement.
350	Parts necessary to coordinate the element with nearby or attached elements are in the model. These modeled items include supports and connections between the elements.	Measurements and information can be obtained from the model without considering information from outside the model.	The actual model of the light fixture. Specific size, shape, and placement.
400	The elements contained in the model are as detailed as they can be fabricated from it.	Measurements and information can be obtained from the model without considering information from outside the model.	Same as LOD 350 with the added information regarding mounting and decorative aspects.
500	The BIM relates to field verification of the built objects.	Already built.	As built.

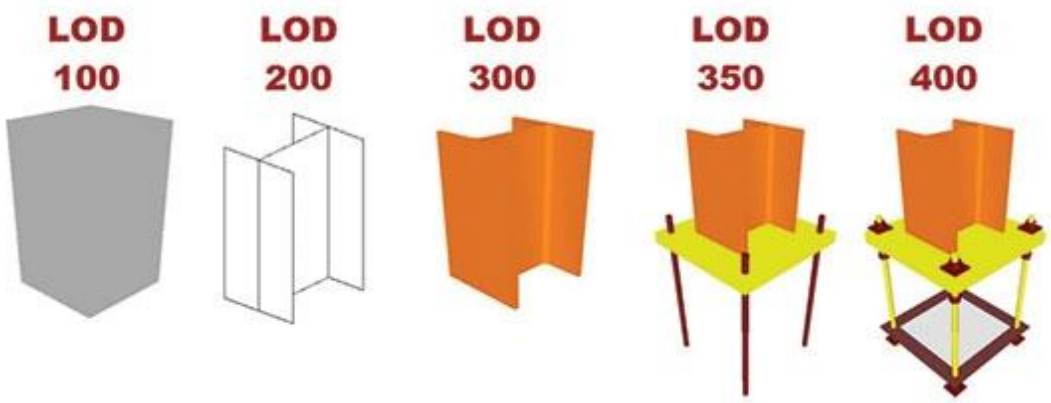


Figure 1 - LOD description (source: https://www.bdcnetwork.com/blog/lowdown-lods-bringing-clarity-bim, 19 march 19).

2.3 BIM implementation

When implementing BIM on the construction site it was found that people with experience from CAD suffered a decline in productivity initially compared to those with no CAD experience (Chelson, 2010). This was according to the research due to an adjustment period. However, after the adjustment period, the people with CAD experience excelled. Older personnel had issues when modeling within BIM as they were not as used to computers. Young personnel, on the other hand, are used to computers but lack the experience of construction.

With complex processes in production, a high level of synchronous communication is needed (Svalestuen, Knotten, Lædre, Drevland, & Lohne, 2017). Synchronous communication is information exchange between persons directly, not via email or models. However, it has been found that visual communication can bring forward better clarity and understanding than audio communication (Wileman, 1993). Since construction projects have a lot of different stakeholders, with the same or conflicting interest, a high level of communication is necessary (Luo & Xu, 2014). Not properly executed communication have negative impacts on productivity and efficiency, and a high level of information transfer reduce waste in construction. Consequences of poor communication can be cost overruns, schedule delays, safety issues and quality defects.

In production, the model will have a higher benefit rate if on-site items can be implemented, for instance placing the crane in the model (NYC Buildings, 2013). It is important to include the information about the reachable area of the crane, and the area of concern, from a production and safety standpoint. The inclusion of on-site items is especially good if the model is considering time. 4D has also shown to have a positive influence on material handling on site (Love & Wang, 2012).

Usually material quantities have been calculated by hand, with new technology this can be done directly from the BIM (Lindström, 2013). With tools such as quantity takeoff material calculations can be done quickly. However, there has been found that

this change has been tough to make happen. Moreover, it is important that the production managers feel that there is something to gain from the new way of doing material calculations. Otherwise, the old way will continue. It is a combination of knowledge within the management as well as an incentive for them. First off, they need to know what they can use the BIM for. Secondly, they must know how to use it to get the information. The case Röforsbron reported an improvement regarding the quantity estimated as it was more exact (Malmkvist, 2013). The fault-rate when estimating from the BIM is much lower than when doing it by hand, and changes are much easier to incorporate.

2.4 4D modeling

4D modeling is referred to when a time aspect is added to the 3D model. Enabling a walk-through of the project visualized throughout construction. By using 4D planning simulations the overall project time decreases (MWH Treatment, 2017). Moreover, risks, changes in design and clashes were reduced. The use of 4D helps in collaboration between the project team and the construction team. Deliveries to the site, sequence, and timing, benefitted from the use of 4D. It was found in the study about MWH Treatment (2017) that the use of 4D in the aspect of MEP installation work reduced the necessary time. Also, a reduction of transports on site and no accidents were recorded.

In a study done by Sediqi (2018) with regards to 4D implementation in the Swedish construction industry, it was found that overall implementing 4D would benefit the processes compared to traditional construction planning. The highest benefit was found connecting to visualization and understanding of the construction workflow. Also, planning in regards to organizing space, logistics, and construction process was highly listed. The barriers hindering 4D BIM implementation could be connected to soft skills, such as knowledge and expertise within 4D. What made the construction companies use 4D BIM was to gain a competitive advantage in the business as well as advance technologically. This study was mainly conducted with experts within the BIM field.

4D BIM is a cost for the planning phase of a project, however, it is believed that it will payback and more with the use in production (Sediqi, 2018). The barriers are mainly due to non-technical aspects, such as organizational challenges, client requests, unclear benefits, and investment issues. The technical issues that effects are mainly: lack of standards, high complexity and software difficulties. By implementing a standard for 4D BIM, having easier software to work with and a general demand of 4D BIM from the client, the implementation of 4D BIM could happen quickly. Unfortunately, there has been little research on the benefits of 4D BIM, therefore more research is needed for 4D BIM to be implemented more.

It was found that 4D BIM visualization was better developed for external objects (walls, ventilation) than internal objects (piping, electrical installations) (Sediqi, 2018). Using 4D to communicate and coordinate proved to enhance the productivity on site. Stated in the report developed by Berglund et al. (2017) is that more advanced simulations on the construction site will identify dangerous situations.

2.5 BIM at the construction site

Paper drawings are still the most common on production sites, but a few test projects have been conducted where all drawings and measurements are pulled from the 3D-model (van Berlo & Natrop, 2014). Usually, projects receive information in drawings, technical specifications and quantity lists (Cousins, 2017). By using these communication channels information gets dislocated, mainly due to the outdated communication tools (Luo & Xu, 2014). Research has shown that paper documents cause loss of information and that it slows down processes, information that all could be delivered within the BIM. However, the transition from paper-based information to digital has caused even longer process times, since it is a new method. By extracting measurements and relations from the BIM, no paper needs to be printed, having a positive effect on the environment (Chelson, 2010).

From the case study presented by Merschbrock and Nordalh-Rolfsen (2016), regarding Oslo Airport terminal 2, the project was completely done with BIM during the rebar phase. It was reported that the BIM made it easier to understand what was going to be built, as all the information was presented and available in one place. Compared with paper drawings where both the plan view and section view might contain information, regarding the same object, the BIM had all information stored. However, if all 2D drawings was excluded from a project, knowledge about the project might get lost (Lindström, 2013). Therefore, the combination is the most beneficial today.

By having an up-to-date model with all the relevant information, complete construction drawings can be developed from the software (van Berlo & Natrop, 2014). In this way, the construction drawings can be produced with all the relevant information for the specific task, making the drawings easier to understand. With less noise on the drawings, fewer faults will happen. Therefore, reducing the risk of re-work and improving the quality. However, the same risk that is possible when paper-drawings are not up-to-date can occur with the BIM (Malmkvist, 2013).

When examining the BIM compared to paper drawings, a lot more information is taken in. As paper drawings are divided into different categories depending on the profession, and the BIM can include all. Helping with better collaboration and understanding of the different professions, as it is easy to get an overall picture of the building (Murvold, Vestermo, Svalestuen, Lohne, & Lædre, 2016). Instead of only

taking in specific information about an profession you take in all information, and the dependencies between them.

Projects have seen increases within safety aspects on the construction site as well as an increase in motivation by the workers (Malmkvist, 2013). When using 4D modeling an increased focus can be put on visualization, enabling different scenarios to be visualized and analyzed. By applying this tool, greater planning can be executed, for instance regarding safety questions (NYC Buildings, 2013). And precautions can be made regarding the safety. It was found by Berglund et al. (2017) that 5 out of 6 found risk hazards would have been hard to detect in regular 2D drawings. As these were found when accessing the 3D model.

With the availability to produce drawings by themselves the construction site will not be dependent on the knowledge of the architects producing the drawings (van Berlo & Natrop, 2014). For some work tasks, the task is too specific to use the developed drawings. Instead of requesting new drawings, with the specified measurements, drawings can be extracted directly from the model. However, it has been observed that this method still takes time, demanding a higher level of planning for this method to work fluently. (Malmkvist, 2013). Collaboration between the site managers and workers are important when extracting the drawings, since it is not about developing drawings rather than providing information without noise. (van Berlo & Natrop, 2014).

The use of BIM has helped with the communication between different professions (Murvold, Vestermo, Svalestuen, Lohne, & Lædre, 2016). As they obtain more of an overall view and information about the project, questions and solutions have been raised affecting the other professions. This is because information often distributed on different drawings are contained within the same model. This is compared to when workers examine different paper drawings regarding a problem. Then questions that are unnecessary often arise because the entire picture is not understood (Merschbrock & Nordahl-Rolfsen, 2016).

Described by the research made by Murvold et al. (2016) and Svalestuen et al. (2017), MEP related work tend to have greater benefit of BIM. Chelson (2010) also points on the importance of constructing a model combining all MEP professions. This enables detailed planning of all installations, proofing that no clashes occur. This might be because installation work are more dependent on other professions, with installation work often crammed in the same space above the ceiling, for instance.

A generally placed component in the BIM can easily be observed by the site management as the specific component and placement (BIMForum, 2017). Therefore, it is important to state to which Level of Deployment the BIM is modeled and that this is communicated to the site managers. Otherwise, all the information in the BIM can

be under-valuated due to one part being not specific enough, as the trust for the BIM is lowered. For the BIM to be used, trust in the model needs to be established.

2.6 Benefits and drawbacks of BIM

Gains in efficiency has been observed with the improvement within RFI (request for information) saves, less re-work and better planning and communication (Chelson, 2010). The lower amount of RFI in a project proves that information is clear and easy to understand, in comparison to 2D drawings. A direct effect of the clarity, completeness, and workability of the BIM. Chelson (2010) argues that construction costs can be divided in half between labor costs and material costs. The labor's time has been revealed to only generate value to the product half of their working time and 35% of their time is a waste due to waiting. The waiting time is most often connected to a lack of information, waiting for material or other professions.

The overall view is that BIM is great to use when trying to understand complex structures (Merschbrock & Nordahl-Rolfsen, 2016); (Malmkvist, 2013). As it is easy to turn and twist to see from the necessary angles, instead of looking at several different paper drawings (Merschbrock & Nordahl-Rolfsen, 2016). However, there were some negatives thoughts presented in the case study by Merschbrock and Nordalh-Rolfsen (2016) as well. Workers had a negative view of having to learn new things regarding something they already knew how to do and the BIM was not necessary for easy jobs. Color-coded objects gave the workers a simple but informative overview. The workers in the study, age differences from 15-50, had close to no difficulties with learning the software. However, it has been stated from other researches that older and more experienced workers have had trouble learning and lacked the motivation to use BIM (Chelson, 2010) (Murvold, Vestermo, Svalestuen, Lohne, & Lædre, 2016).

Found by the case study done by Chelson (2010) several benefits of BIM in construction was found:

- BIM usage brings a significant reduction in the number of RFI on projects.
- BIM usage causes a reduction in the number of change orders on projects.
- BIM usage reduces the amount of rework and field personnel idle time.
- BIM has a positive effect on schedule accuracy and speed.
- The BIM process increases production rates.
- The shop drawing process is shortened and simplified by BIM usage.
- BIM enables greater levels of prefabrication
- Quality of the finished product is enhanced through the use of BIM by contractors.

One of the great drawbacks with BIM has nothing to do with BIM, but with the ruleset behind the construction industry. The BIM is not considered as something to

build after today, as the drawings and specifications are ultimately deciding (Englund & Grönlund, 2018). Contractual documents are not supporting the ongoing technological progress in the industry. As all standards (AB04, ABT06, and ABK09) support design information regarding paper drawings. There are often disclaimers used when launching the BIM to the production team (Bedrick & Vandezande, 2018). Describing it as something not specific, not possible to build after and lower ranked than regular drawings. It is of great importance that the site-personnel feel comfortable using the model for decision making (Englund & Grönlund, 2018). Otherwise, it will only conclude in an extra workload.

3 Method

The methods chosen to conduct this thesis was a combination of interviews, a survey, and observations on site. The interviews and observations were conducted to get quality results, the survey was to get an overall quantitative picture of the studied company positioning towards the subject. The conducted interviews were semi-open, as the interviewees could elaborate when questions were asked, but not spin too much off topic. The survey was mainly based on close-ended questions. This because it was aiming for a broader audience, with less specific knowledge and therefore should be quick to conduct. The on-site observations were conducted spontaneously as things happened on site.

All interviews and survey results were conducted in Swedish, as to not limit the understanding and answers. The Swedish answers were then thoroughly translated into English, for the use in this text. There were also interviews conducted over Skype, to gain knowledge from other parts of the country.

3.1 Interviews

When obtaining qualitative data, interviews are the most common way (Jamshed, 2014). Interviews can either be structured, unstructured or semi-structured. Structured interviews have a strict questionnaire to follow, unstructured interviews are more like a conversation.

3.1.1 Preparing the interview

When conducting an interview there is a difference between interviews for qualitative data and quantity data (Bertram, 2009). For quantitative data, it is better to conduct strict interviews. To conduct qualitative interviews, it is important to let the interviewee elaborate and not feel tied down. By conducting a semi-structured interview one can let the interviewee elaborate regarding their interests and at the same time keep the interview based in the regarded subject area (Jamshed, 2014).

The focus of the interview questions has been based on the research questions of the thesis. By starting with easier questions, and ending with more elaborate and futuristic ones, the hope is that the interviewee is comfortable and open-minded (Sociology Harvard, 2018). It is also recommended to record the interview for availability to go-over the material again, and full focus can be put on conducting the interview.

3.1.2 Conducting the interview

To enable the interviewees to be as open-minded and honest as possible the interviews were conducted in closed off-sections and anonymously. Therefore, the answers and discussion were only heard by the author and the interviewee. There was a sheet of questions, not provided to the interviewee beforehand. To not direct their

thoughts and answer in a specific direction. However, they knew the topic of the interview. So, they were not completely off-guard. The interview was not strict to follow the question on the sheet, as the interviewee could elaborate. However, retained back to the subject if wandered off too far. Also, the interview was organized in three sections. First, a few open questions regarding BIM, in general, was asked. Secondly, we went into how they use the model today in projects, either the one they were at or one before. Thirdly, we went into questions regarding the future and visions. These questions contained technology that exists today but is not used in the general projects. These choices were made to get as qualitative results as possible.

3.1.3 Analysing the interviews

The results from the interviews will mainly give qualitative data, this data can be analyzed differently depending on the type. The data was recorded and summarized on the same day or the day after. Thereafter, the data was categorized in several categories and analyzed. As the interviews were held in person, face to face, facial expressions, and general expressions could be taken into consideration while the interview was conducted. However, as the data was dissected from audio to text information regarding facial expression will be lost.

3.2 The survey

Surveys are a quick and easy way to retain quantitative results (Svensson, 2015). Excluded are pre-thoughts regarding gender, ethnicity, and age that could affect the interviewer. However, there are several disadvantages that make the survey not work as a qualitative process. Most importantly are the limits of asking follow-up questions and making sure that the respondent has understood the question. One could also not expect a high frequency of answers when sending out a survey, usually, 25%-35% is estimated as a response rate for postal surveys (Fellows & Liu, 2015). Even lower is expected on internet surveys.

3.2.1 Preparing the survey

When preparing the survey, considerations of the target group should be taken into consideration. The words chosen and how the questions are formulated are essential to make people answer (Bertram, 2009). The main rule is to keep it as simple as possible. The start of the survey should be easy and straight forward to get people started.

The survey contained mainly closed-end questions, with either multiple-choice or single-choice questions. This was done to get as many answers as possible. Overall, the questions allowed several answers, multiple-choice, to not hinder the person answering. When creating the questions the importance of having both negative and

positive answers was important. Also, most questions contained an “other” option. Where the person had the ability to fill in their own answer.

3.2.2 Analyzing the survey

When the survey had been closed from more responses the results were analyzed. This was done by looking at the numbers and the spread of the answer ratios. Thereafter, further analysis was done by singling out data, for instance only looking at the answers where they had answered that they had training in model use. This was done to check for any correlations.

3.3 Observations

When visiting sites, observations were made to see what the personnel did without knowing it, with the model. Accomplished by just being around the personnel on the site during regular work.

3.4 Research ethics

Important for the survey is to keep the information obtained from the interviewees/site visits true to its source. And when conducting the interviews let the interviewee take the discussion where they want, not feeding them with answers. The survey was kept anonymous and sent by e-mail, both to keep the results true and not print unnecessary amounts of paper, saving the environment.

When doing the literature study, it is important to consider the information obtained in a scientific way and not to do plagiarism. As well to refer to the work examined and used in a structured and organized way. To avoid FFP, fabrication, falsification, and plagiarism (Stewart, 2011). Cultivate openness, integrity, and accountability regarding the thesis conducted, as the author should have full responsibility for the published work.

4 Results and analysis

In this chapter, the results and analysis from the survey and the interviews will be presented. The results from the observations are presented within the results from the interviews. The chapter also includes information from within the studied company, internal documents, as to give a background to BIM work in the company.

4.1 BIM in the studied organization

The studied company is one of the largest companies in Sweden. It operates in several different areas, such as building houses, roads, and housing. The company sees the model as a tool to facilitate communication and even ease communication between different languages. The model also helps with communicating between different professions, as to how they should collaborate. This chapter is mainly based on internal documents.

The studied company has in Gothenburg started a process to implement so called *digital leaders* in production, which goal is to have one digital leader on each construction site. These *digital leaders* are supposed to enable a support with digital tools so that others in the production team has a designated person to ask if a problem arise, these are also the communication channel for the corporate *digital leaders* who work on a bigger basis. This will hopefully enable a quicker spread of knowledge and competence as well as an understanding of what is needed. The digital leader will work 100 % on the construction project with designated time for digital work determined from the size of the project. With this project, they are also creating best users in different softwares. Creating pro users in some softwares so that the knowledge is closer to production.

The studied company has adopted a version of AIA's LOD description (Studied company, 2019). A rough estimate of the arranging between the company adoptions of LOD is:

- LOD 100 – Proposal document, Projection
- LOD 200 – Systems act, Projection
- LOD 300 – Building document, Production
- LOD 400 – Manufacturing document, Production of prefab elements
- LOD 500 – As built document, Facility management

When using a 3D model within the production the studied company expects profits due to a better consensus and clearness. Hence, fewer misunderstandings. They also point on the use of BIM to better communicate with site workers, even breaking language barriers. The studied company sees the BIM as a complement to the paper drawings, to get a more complete picture of the building. This way of working affect the planning, production, working environment as well as communication.

For the BIM to be successful in the projects different guidelines are used. First, keeping close collaboration with the client and update the model so that it can be used throughout the entire project. Secondly, to have a certain knowledge level within the production team, matching the aims with the BIM. Thirdly, concrete goals for the usage of the BIM in production.

Regarding paper drawings in the production, the studied company applies advanced drawing management. This method enables search ability within the documents and drawings. Benefits are made due to that documents are always available and updated. Hence, ensure those using the documents that they are always correct. For this to work, it is important that it is a well-defined document structure, well communicated and that the people working with the tool understand and are comfortable with it.

4D-planning is not used that much by the studied company at the moment, but some test projects have used it. The company argues that 4D-modelling enables more detailed planning, which gives the opportunity to optimize the production phase. Visualization of planning for different professions are also available. However, to be able to use 4D-modelling a very well structured timetable and model is necessary.

By using the quantity takeoff tool you reduce the amount of double-work, time spent executing the task, and you get a more precise amount quantified. However, it is very important that the BIM contains the required information and at the specified LOD for this to work. The quantity takeoff tool is also called information take-off, ITO. The studied company has developed several basic ITO's available to all in the company, enabling a higher amount of use as the user only need to have the knowledge of how to use the ITO, not create it.

When the studied company have used screens, tablets or BIM-kiosks they have seen an increase in information distribution and having updated information available. The importance lies within the system to be stable, simple and located in the correct locations.

Virtual reality, VR, is regarded as a tool that enables clear communication, higher understanding, and preparation ahead of work and the work being executed. With the help of VR, it is easy to get a visualized picture over what is going to be built and participation from all professions. It is important that the model is of high quality and dividable into segments. Moreover, the required technical equipment needs to be available for the workers on the production site.

The company aims for their projects to attain a Level of Development corresponding to LOD 300. Their requirements enable the following tools to be used from the model:

- Work site outline plans within the model
- Coordination

- Collision control
- Checking
- Information outtake
- Work preparation
- Quantity takeoff
- 4D-simulation

The company is trying to push on the digitalization within the company from the bottom up, instead of the more usual top to bottom (Hagman, Mohammadi, & Wibeck, 2018). It shall grow from the bottom. The production teams are participating in workshops regarding digitalization. They argue the importance of the production personnel feel that they are in control. Hence, lowering the stress levels. BIM is to keep safe and secure information throughout the project (Areno & Mohammadi, 2018).

Important when working with digital tools, is the easy-adoption rate within the scoped workers (Hagman, Mohammadi, & Wibeck, 2018). The tools cannot be hard to handle nor use. Hence, workers will not use it if it is too much of a struggle. It is also believed that if one experiences a good tool they will share it with others (Hagman, Mohammadi, & Wibeck, 2018) (Areno & Mohammadi, 2018). This is one way the company sees the spread of digitalization going and a feel of the push from the bottom. “Because it is better” does not work as an incitement for change (Hesselgard & Mohammadi, 2018). The benefits need to be visualized.

The BIM digitalization within the company has spread from the tech-edge and large construction projects to even be used on smaller projects (Hagman, Mohammadi, & Wibeck, 2018). In these smaller projects, the drive from the on-site personnel has been very important.

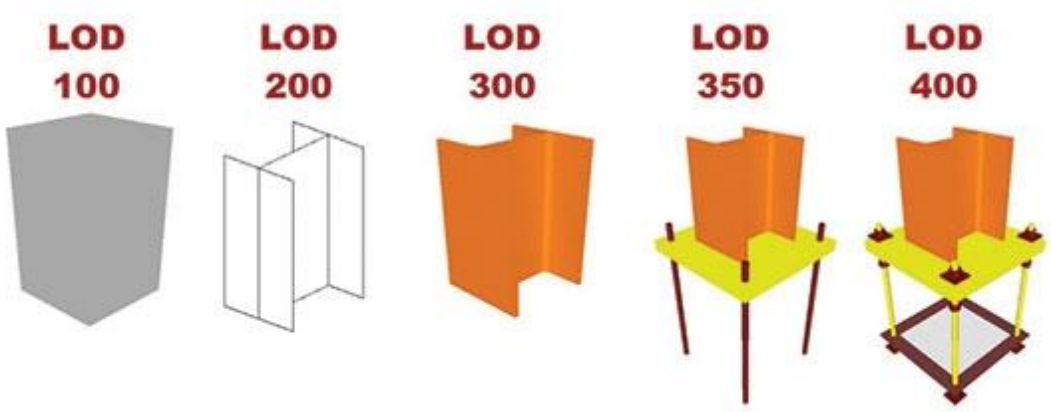
If the BIM is to reach the productivity levels expected, collaboration, standards, and generic tools are necessary (Hagman, Mohammadi, & Wibeck, 2018). Hence, the construction industry is much more complex than the industrial industry. Due to the great number of stakeholders and constant new organizations.

The studied company works with putting digital expertise personnel closer to the projects (Areno & Mohammadi, 2018). This is done by having digital coaches within the organization who drives the change in the company, with a lot of focus on the use of digital tools in production. They also allocate one person in the production team with responsibility of digital tools.

4.2 Result survey

The survey was sent out to 136 people within the Construction Company, supervisors, managers or planning engineers. 55 of these answered, resulting in a 40.5% answer

frequency. Which should be considered good, considering that 25%-35% can be expected according to Fellows and Liu (2015). The survey was sent out in Swedish to generate a higher response frequency. Thereafter, the graphs and tables have been thoroughly translated into corresponding English. Also, in the survey the LOD levels were explained by text and image, to increase the understanding of the respondents. For example, LOD300 – objects in the model looks like the real object. Placing, distances and information can be used from the model. The same was applied when describing 4D and 5D.



Figur 2 - LOD description (source: https://www.bdcnetwork.com/blog/lowdown-lods-bringing-clarity-bim, 19 march 19)

The respondents to the survey had a good spread overall, with more respondents of young age and supervisor position. This could be considered the general statistics of the available respondents. Therefore, the pre-information is valid in regards to those who have answered the survey. We could also see that the general skill level of using the model is quite low. With an average rating of 2.62.

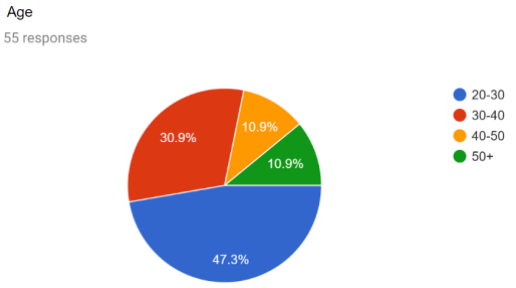


Chart 1 – Age

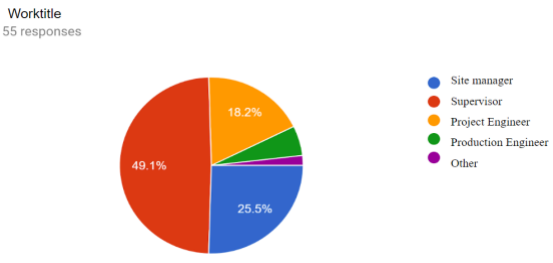


Chart 2 - work position

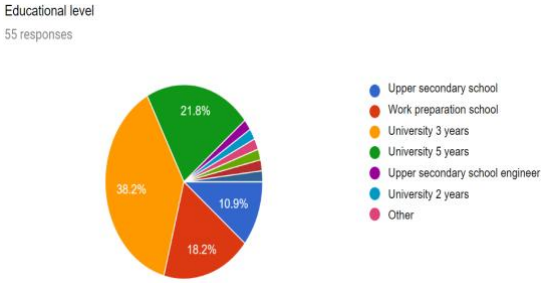


Chart 3 – Education

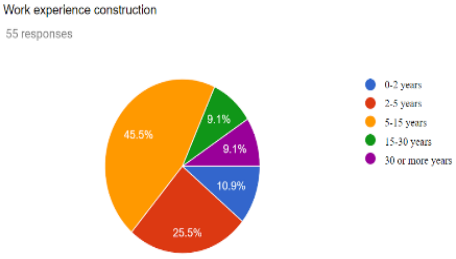


Chart 4 - work experience

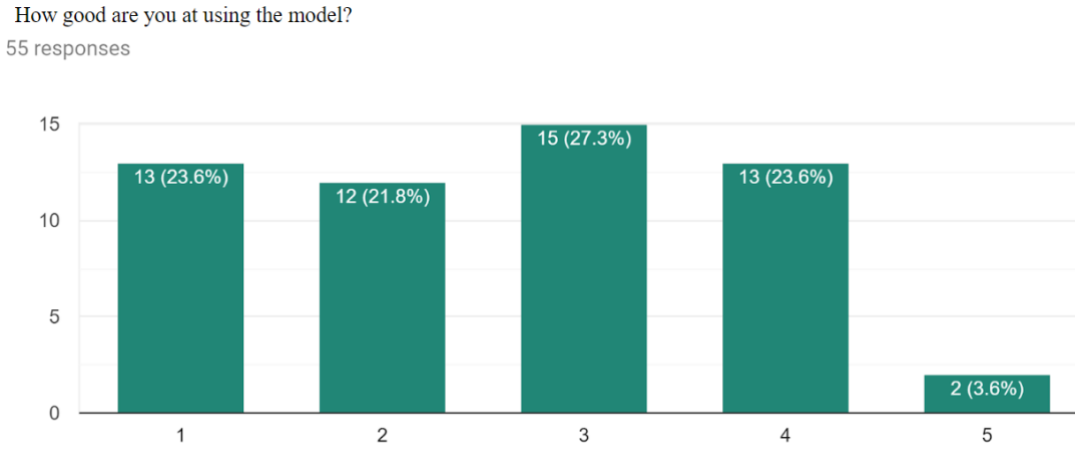


Chart 5 - How good are you at using the model?

Around 50% of the respondents had training in how to use the model, and almost all wanted to have more training in how to use the model. Also, the quality of the BIM was requested to be higher for the respondents to use it at an optimal level. Hence, the majority wanted as much information as possible in it. This gives the perception of that the respondents are positive to BIM use and see the benefits with it. However, most people do not trust the model for making decisions and therefore use paper drawings, as visualized in chart 10.

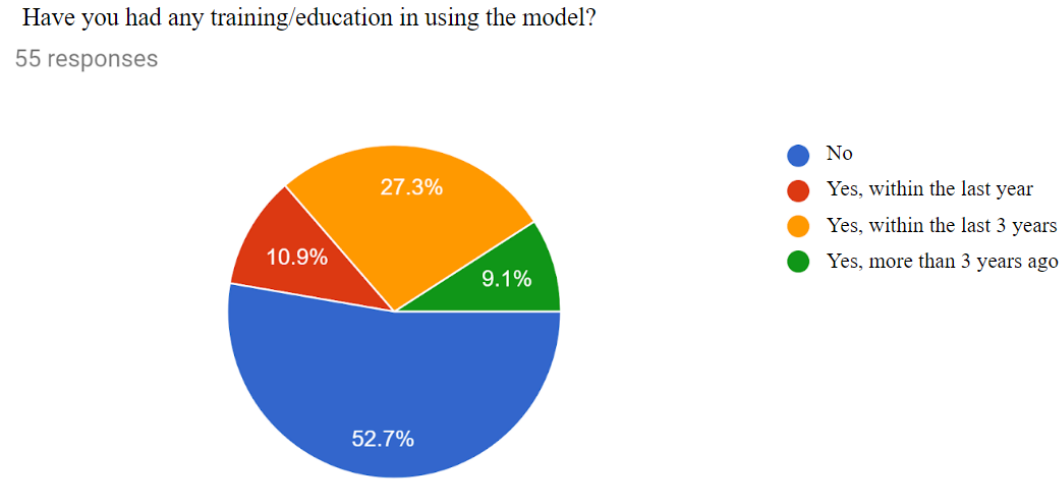


Chart 6 - Training within model use

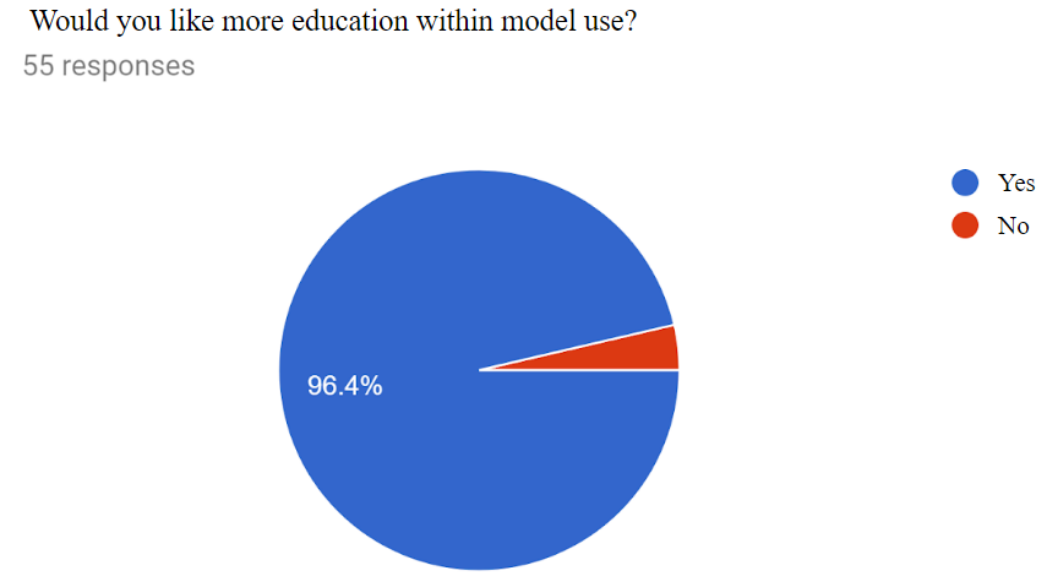


Chart 7 - Would you like more training in model use?

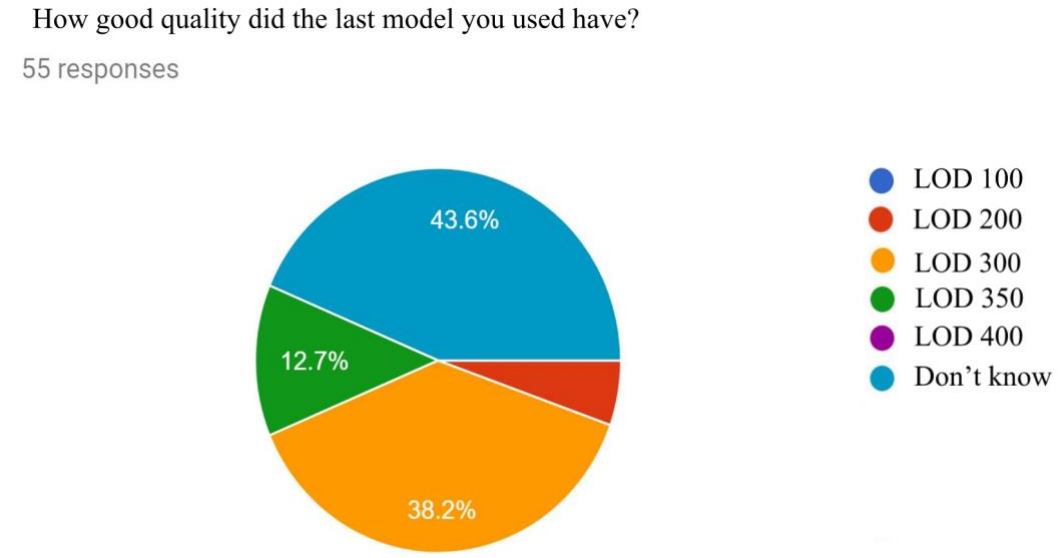


Chart 8 - Quality of last model used

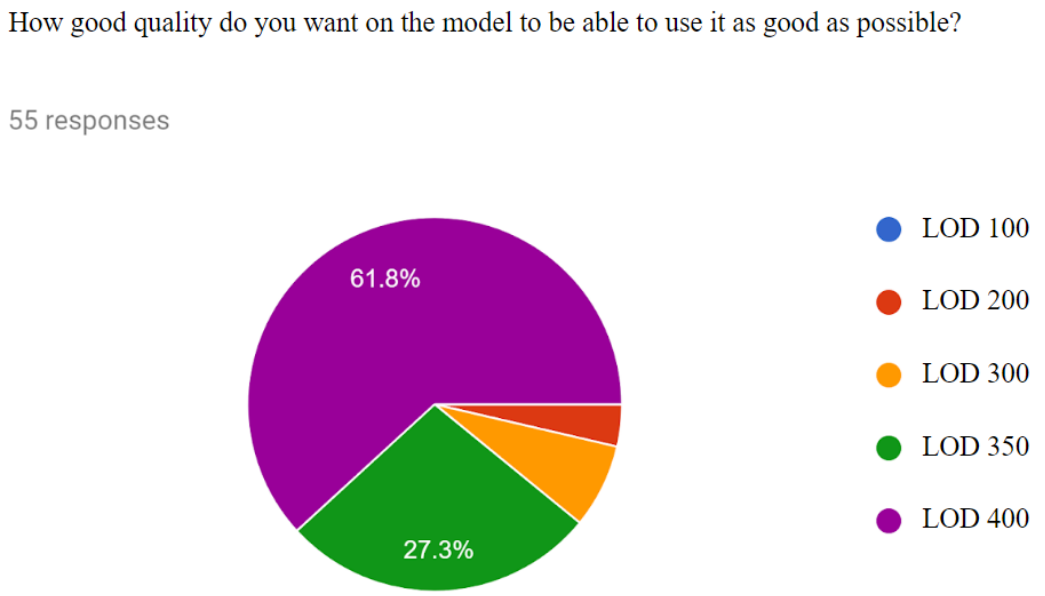


Chart 9 - Quality of model wanted

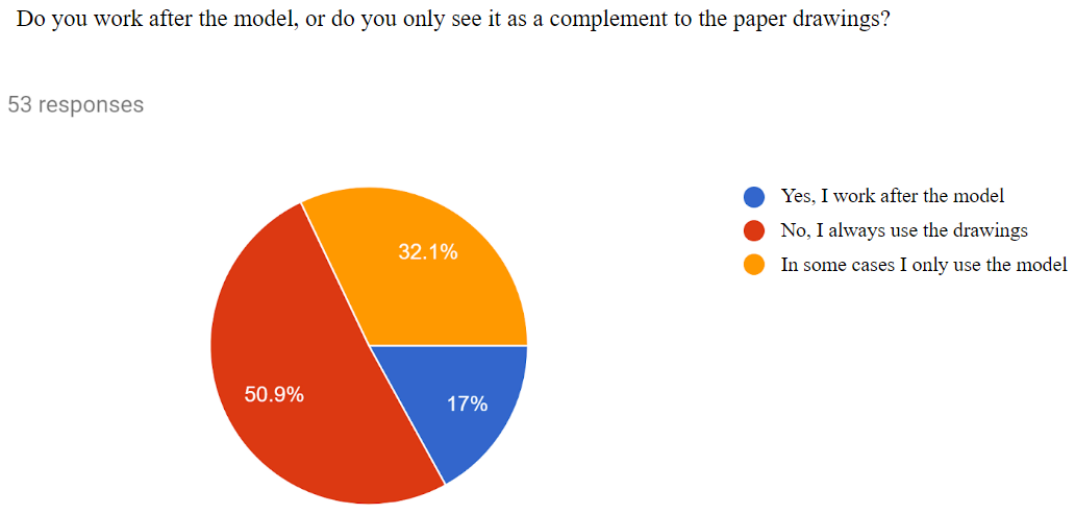


Chart 10 - Use of model or paper drawings

4.2.1 Model use today and in the future

Found in the survey is that most people are positive to the model. But, that they either have a lack of competence in using it or that the model does not have the necessary quality. Most respondents use it either because it makes their work easier or because of the innovative incitement, developing oneself. Where the model has helped the most is with getting an overall picture of the project, some work tasks that have required a lot of time before now take less and help with planning for workers.

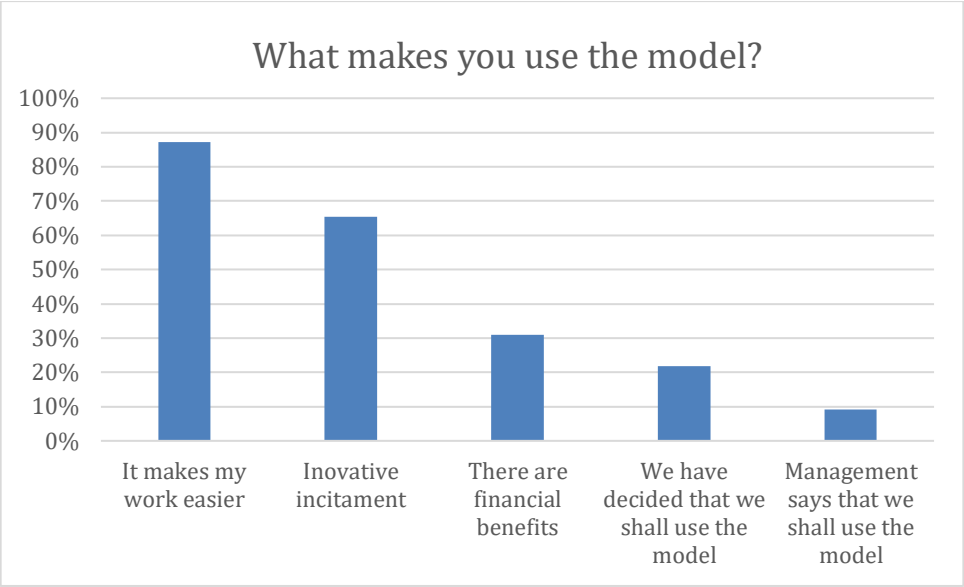


Chart 11 - What makes you use the model?

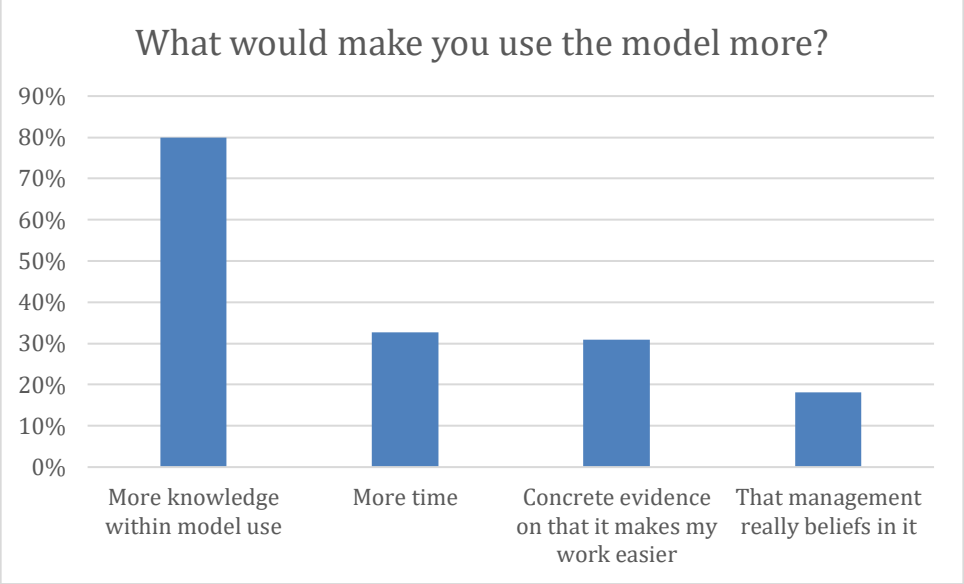


Chart 12 - What would make you use the model more?

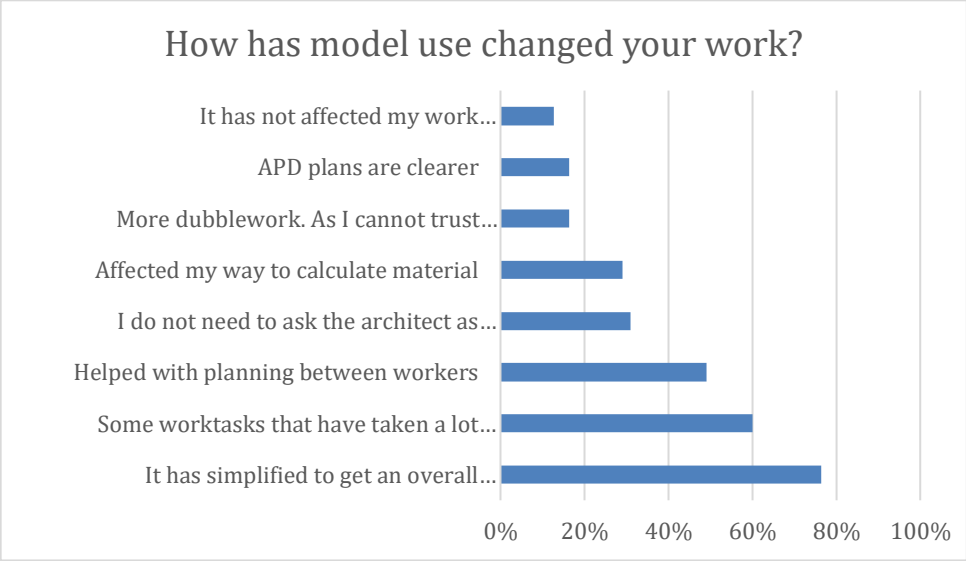


Chart 13 - How has model use changed your work?

The model is mainly used for visualization purposes by the respondents, with a bit over 70% claim that they use the model in this way. Other areas of use, landing at around 40%, are collision control, coordination between workers, information accessibility and planning. However, when asked what the respondents want to use the model for quantity takeoff is the most popular, although all increase massively. The reason to why they cannot use it as they want, is mainly a lack of knowledge and that the models lack quality.

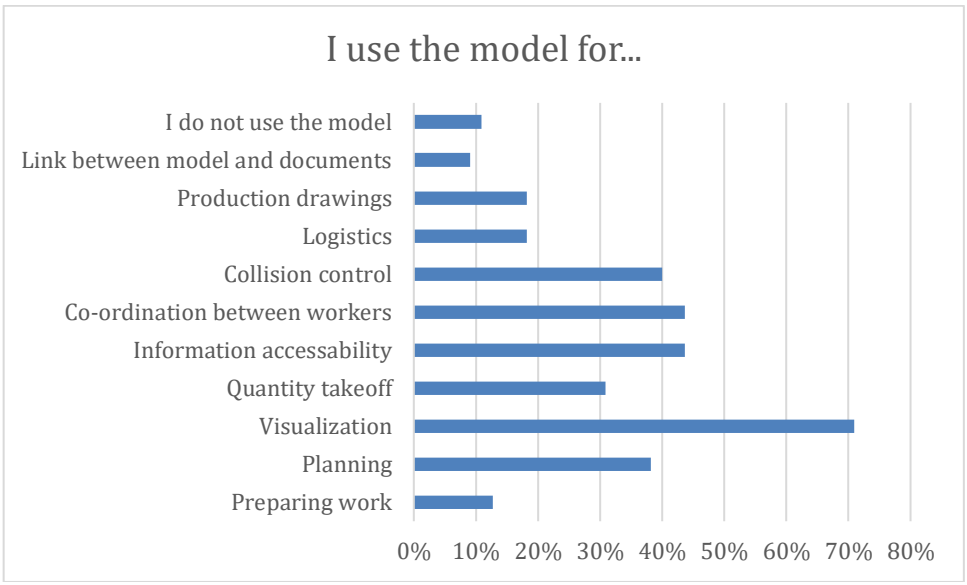


Chart 14 - Model usage

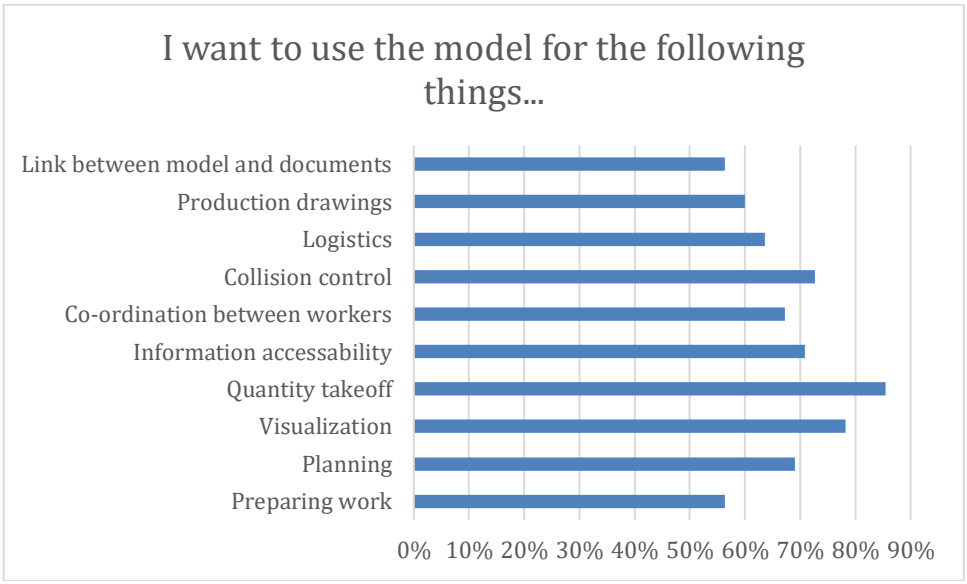


Chart 15 - Wanted use of the model

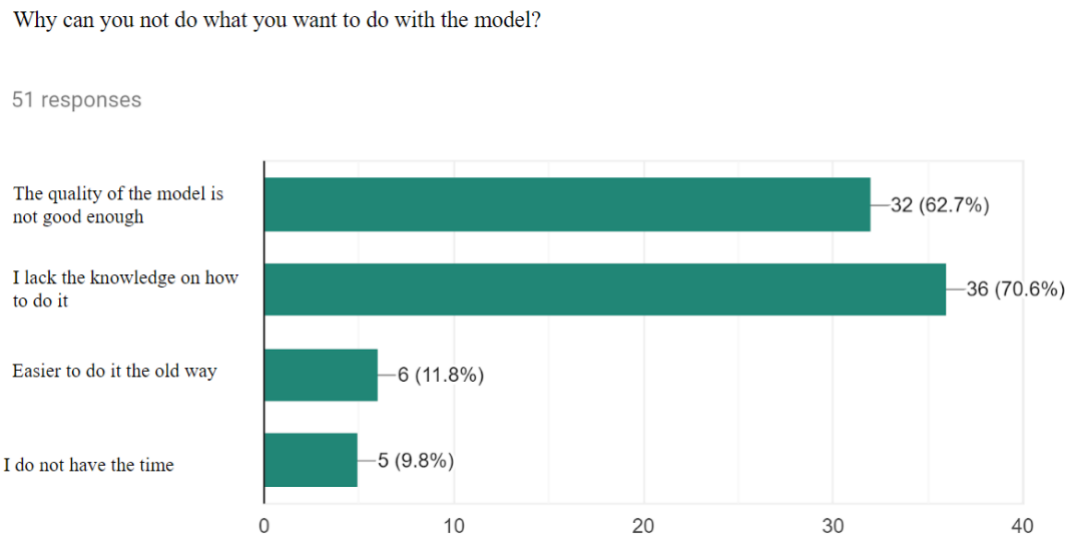


Chart 16 - Reasons of not being able to use the model at wanted level

There is a lot of interest to work with more advanced BIM, such as 4D and 5D. However, there is a concern that the results are misdirecting, because some respondents might just have chosen the highest version. With the higher level of BIM, the respondents want to use it for better visualization and understanding as well as to be able to better plan for the different workgroups. There is also a belief in using it in regards to follow-up on time for different tasks and safety aspects.

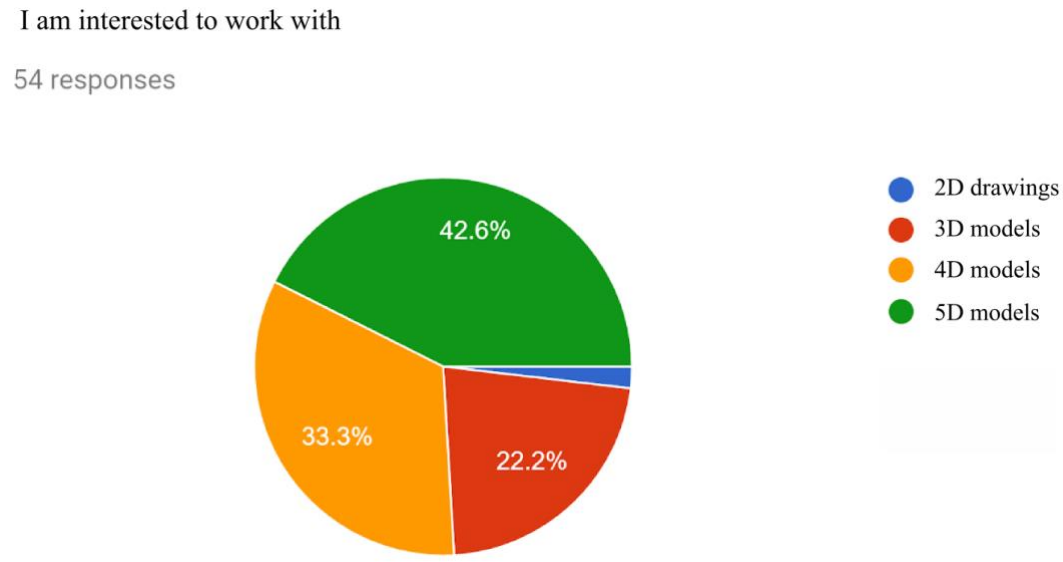


Chart 17 - Level of BIM interested to work with

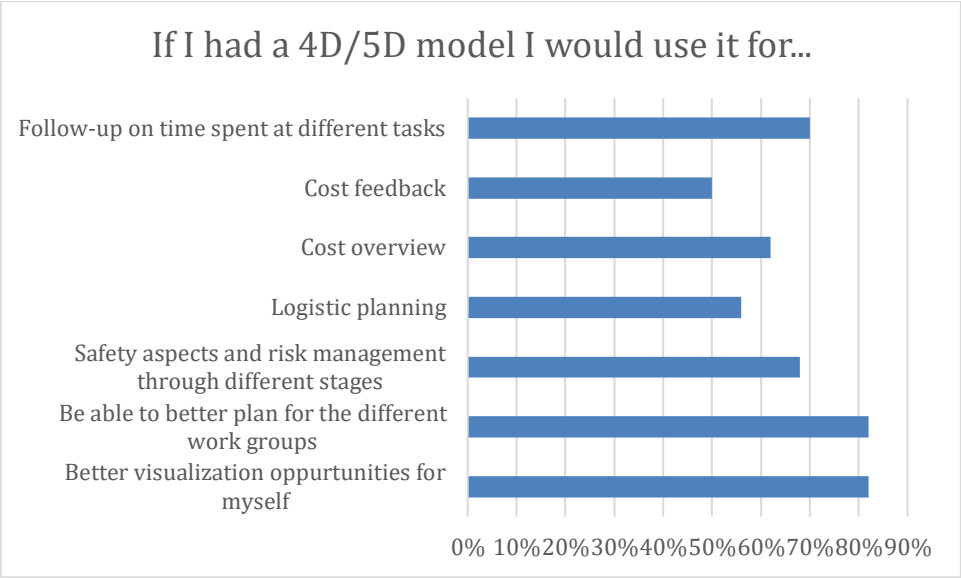


Chart 18 - what I would do with 4D/5D BIM

4.2.2 Correlations from the survey

In this section correlations between interesting factors from the survey is presented. This is done by either excluding data or including data.

4.2.2.1 Superior users

Of those who consider themselves good in model use, 4 or 5s, their answers were pulled from the other for further research. It was found that a higher percentage had training in model use, with 66,7% compared to 47,3%. Therefore, they also use and trust the model more, as shown in chart 20.

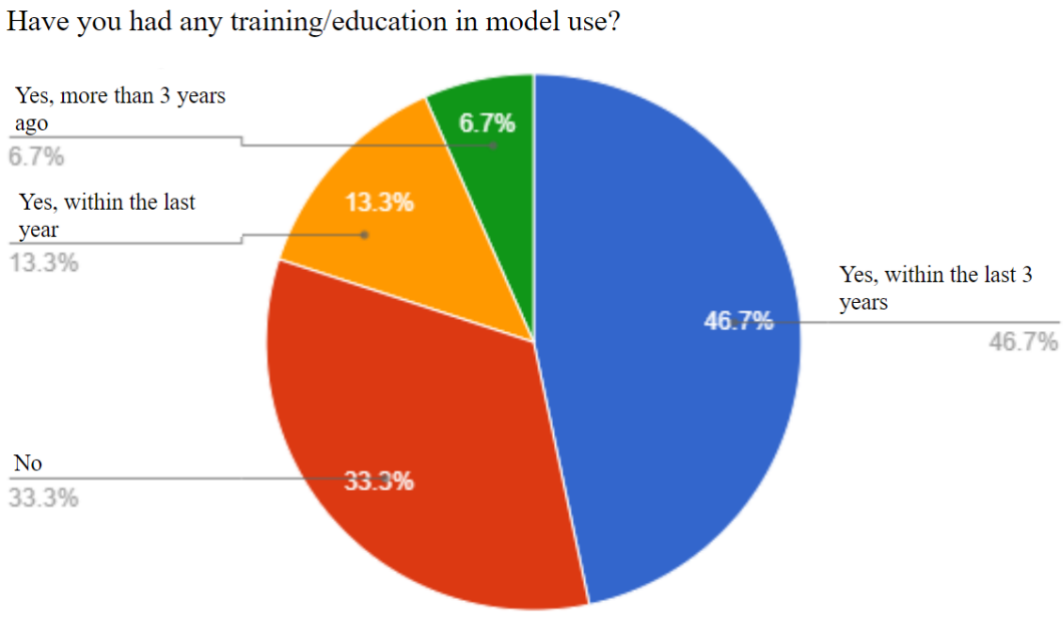


Chart 19 - superior users - training

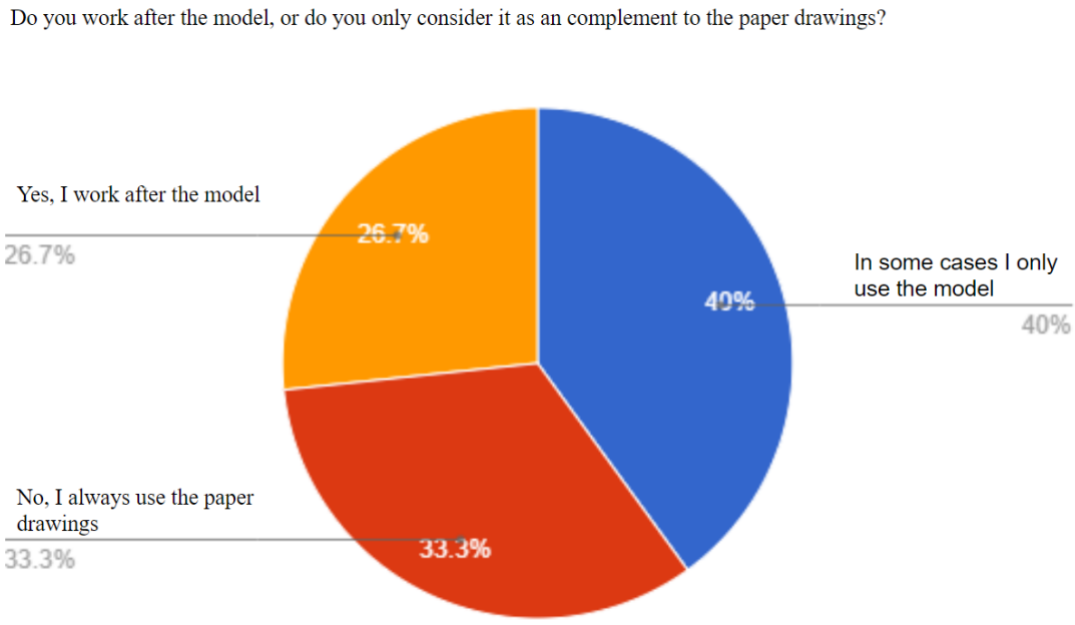


Chart 20 - superior users - Trust in model

Further, analyze was made on what they are doing and what they want to do with the model. All but one state that they use the model for visualization purposes. Compared to all respondents these excel at using the model for material calculations. They also state they cannot do what they want to do with the model due to the lack of quality in the model, and not their skill as is the general view.

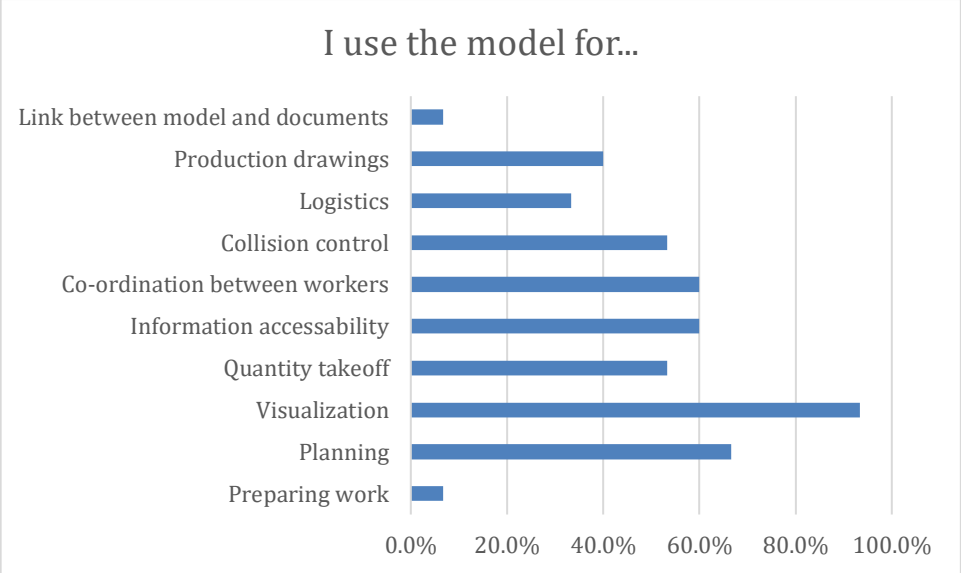


Chart 21 - superior users - model usage

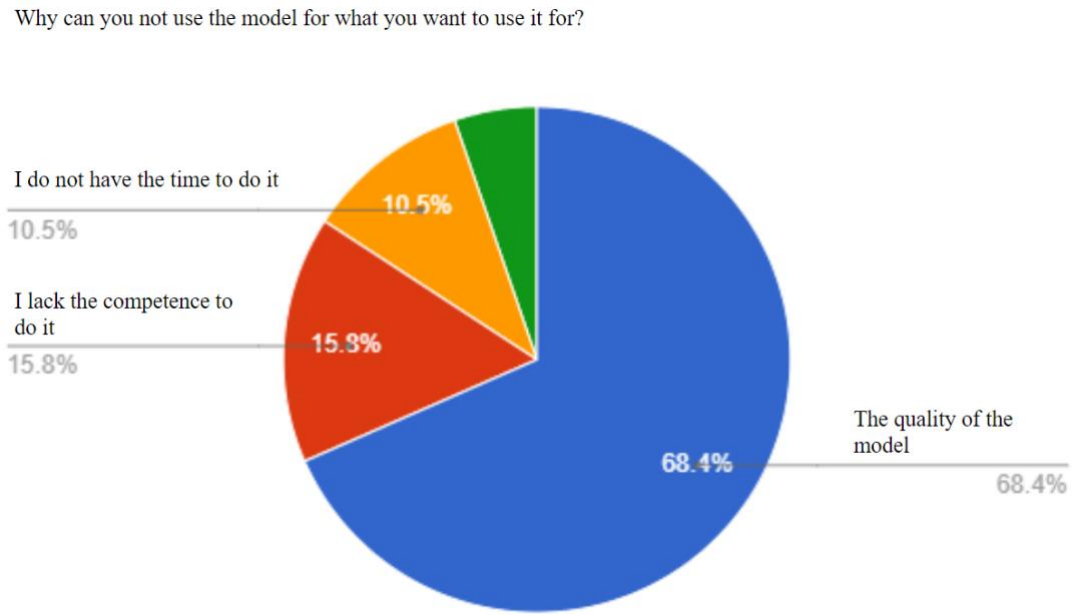


Chart 22 - superior users - why I can not use the model for what i want.

4.2.2.2 Educated responders

Of those who had earlier training in model use, a total of 26 respondents, their results from the survey were pulled from the others. However, the majority of the respondents still want more education in model use. The average rating of how good they were at using the model was raised from 2.62 to 2.85. The trust in the model, as to if they used it for decision making or used paper drawings was similar to those who considered themselves good with model use.

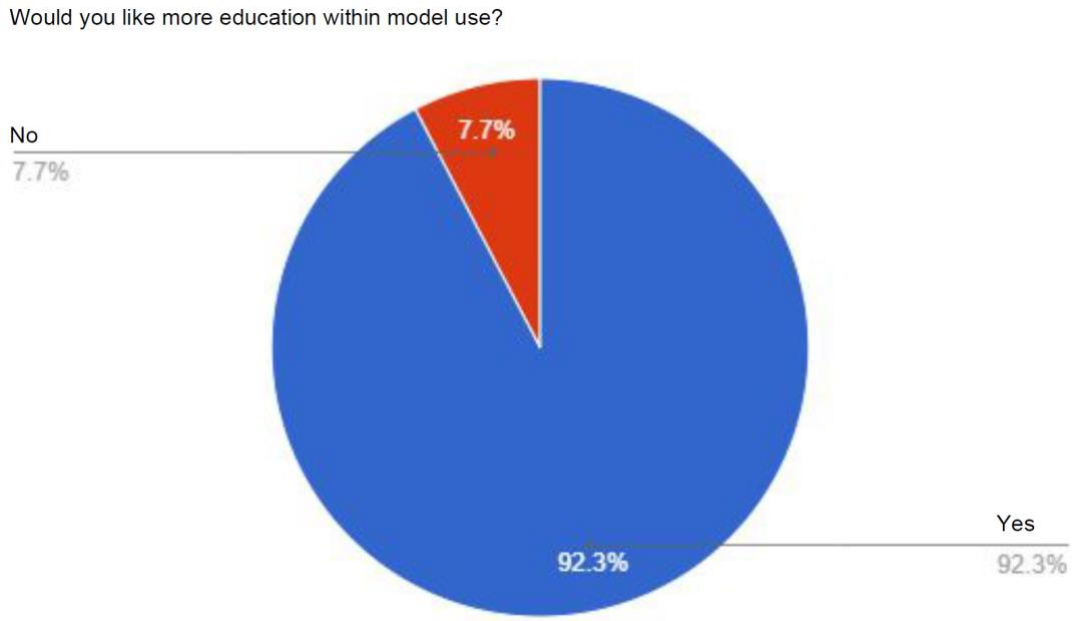


Chart 23 - educated responders - would you like more training?

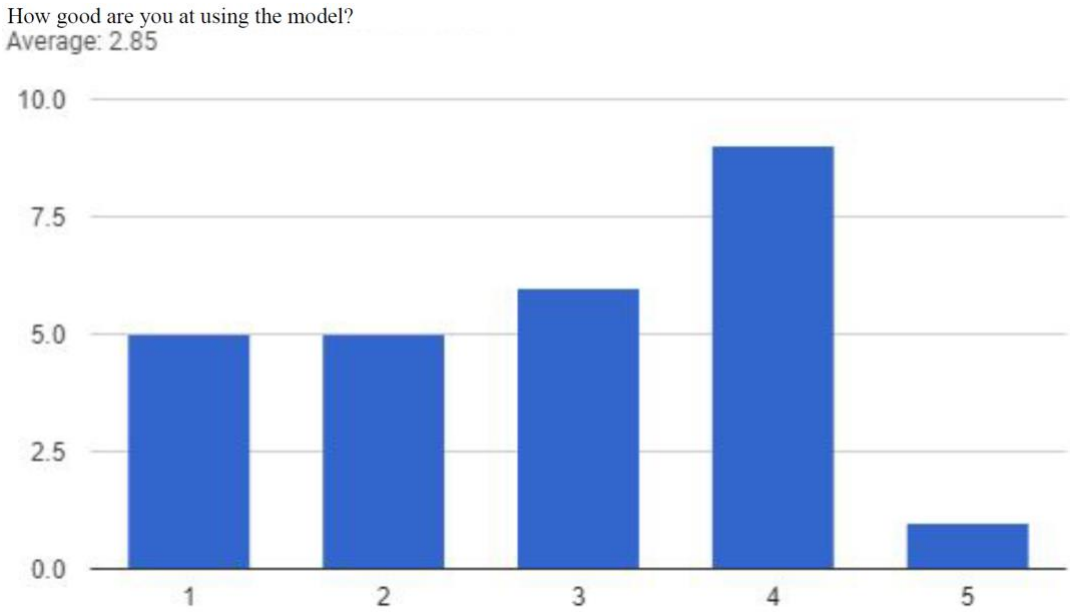


Chart 24 - educated responders - skill level

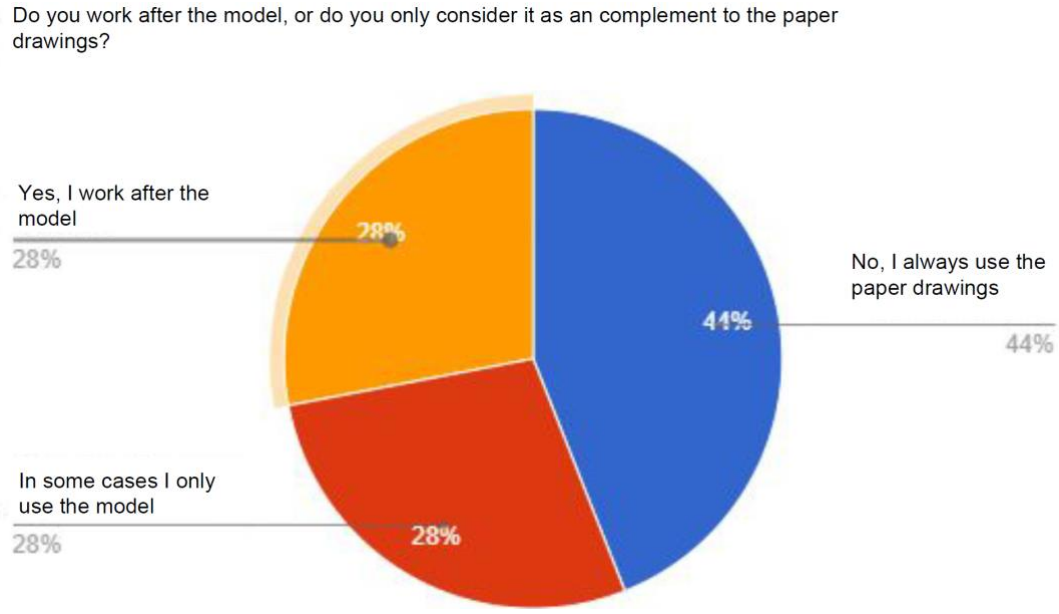


Chart 25 - educated responders - trust in model

Further, it was analyzed what they used the model for and the statistical difference between all respondents. Interesting is that the percentage that does not use the model goes up. Also, visualization purposes go down slightly. However, we see an increase in such things as quantity takeoff, planning and production drawings. The reason behind why they cannot use the model for what they want is similar to the average answer, compared to the superior users. The reason being both lacking knowledge and the quality of the model.

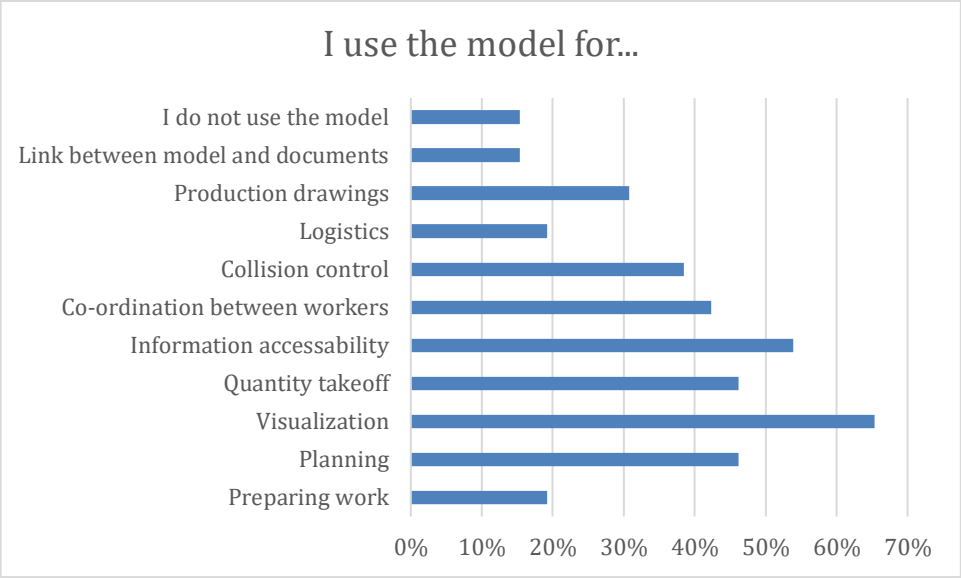


Chart 26 - educated responders - model usage

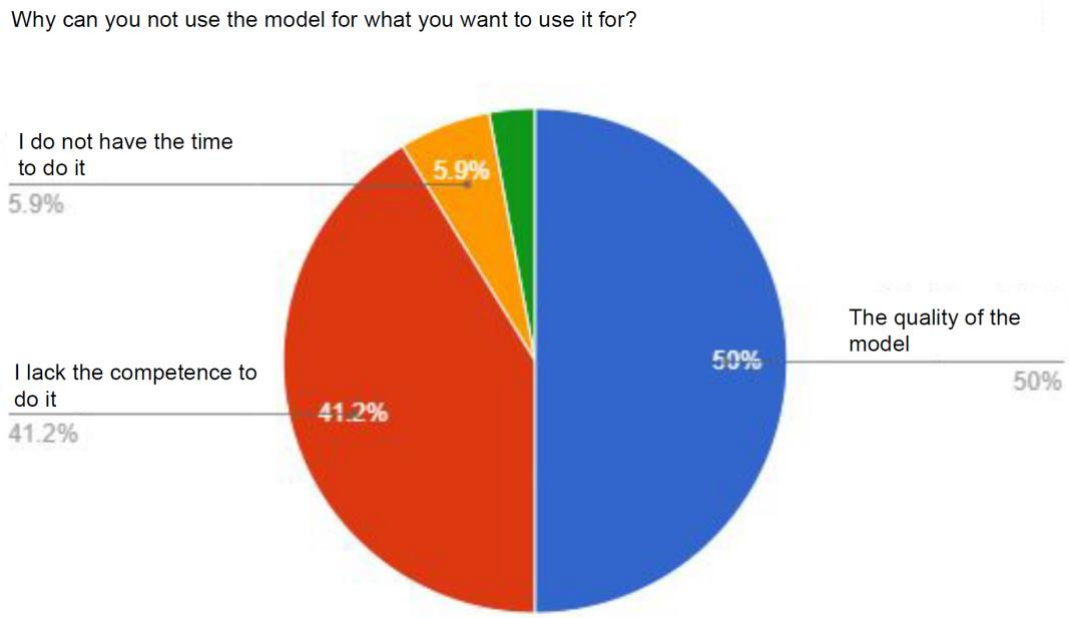


Chart 27 - educated responders - why I cant use the mode for what i want

4.3 Result Interview

In this chapter, the results from the interviews are reported. It starts with a brief description of the interviewees. Thereafter, the results are divided into subcategories that emerged from the studied results.

All interviews have been conducted within the studied company. The people have either been recommended by my supervisors or by the interviewees themselves or completely random by an interest of conducting the interview. Most of the interviewed are on-site personnel. However, PLIT was interviewed for a bigger understanding and vision even though s/he does not work in production, but have experience from it.

PLIT – Works as a project leader with IT in the construction company. Around 40 years old. With previous experience from being a constructor and is educated as a civil engineer.

SC1 – Works as a supervisor at the construction company. Around 30 years old. Educated as a construction engineer and has previous experience from working at an architecture company.

SC2 – Works as a supervisor at the construction company. Around 30 years old. Has previous experience from being a carpenter for 10 years.

SC3 – Works as a supervisor at the construction company. Around 25 years old. Has previous experience from being a carpenter for about 10 years.

SM1 – Works as a site manager at the construction company. Around 40 years old. Has previous experience as a carpenter.

SC4 – Works as a supervisor at the construction company. Around 25 years old. Educated as a civil engineer.

SC5 – Works as a supervisor at the construction company. Around 25 years old. Has previous experience from being a carpenter for about 5 years.

SM2 – Works as a site manager at the construction company. Around 30 years old. Educated as a civil engineer.

DL1 – Works as a digital leader at the construction company. Around 35 years old.

DL2 – Works as a digital leader at the construction company. Around 25 years old.

4.3.1 Visualization and understanding

In the following chapter the results from the interviews is regarding is presented. How the model helps to understand different issues and how it has, and can be used on the construction site.

4.3.1.1 Understanding

A common theme between the interviewees is that they believe that the BIM gives them a clear and good overview of the project, on any structure built in the project. (SC1, SC2, SM1, SC4). However, it is still regarded by some that the drawings are necessary to get detailed information (SC1, SM1, SM2). How the different building parts collaborate is easier viewable in the BIM, especially for less experienced personnel, as the experienced can visualize it mentally better directly from drawings. However, there is benefits generated by the BIM for more experienced personnel. PLIT spoke of that even further information was found, and SC1 that it was used for double-checking information.

”The human brain works like that, we visualize stuff in 3D and we experience stuff in somewhat 3D. Therefore, of course, it is much easier to understand a 3D model rather than a drawing. “– PLIT

“Something happens in the brain when it moves, rather than a still, you connect things quicker” – SC3

PLIT currently view BIM as a visualization tool, as the building need to be understood before being able to start building. This is made easier with the help of BIM, as more ensured decisions can be made with the help of BIM. Therefore, when a problem occurs the BIM is often accessed first, rather than the drawings (SC1). However, when combining BIM and drawings, the discussions have excelled (SC3, SM2). Solving problems earlier and more efficient. Even considering areas where experts have been involved they have understood and relied on the BIM.

Drawings, such as rebar-structures or installation, has its own language, which takes several years to master (PLIT). When studying drawings information disappear through the process of visualizing in somewhat close to 3D, in 2D, which then is interpreted to 3D as-built again. Even if you are looking at the same drawing, there is uncertainty if the drawing is interpreted and visualized alike.

Projects with a high density of installation tend to benefit more from the use of a 3D model, SM2 described his project as almost impossible to do without a 3D model, due to the high density of installation. Considering that the specific 2D drawings for each profession were hard to understand and visualize, combining them was almost impossible. With the help of the 3D model, the level of understanding became higher. Therefore, more responsibility and ensured decisions could be made regarding the

installation work. In an earlier project, there was no 3D model, therefore some collisions between installation happened. Hence, SM2 appreciated the 3D model even more during this project.

4.3.1.2 Planning/Used in production

When planning the work order for a project the BIM can be very helpful, even without the use of 4D. As the visualization is instant by the BIM the brain can focus on conducting an optimal time-table (SC2, SM2). SC3 uses the model for collaborative planning between the different professions, and have felt an increase in co-operation between professions. This since you can see each other's work in the model, compared to the drawings. Also, when the workers now have questions they always ask for the 3D model, and the supervisors also consult the 3D model first (SC3, SC4). Even when there is a discussion within the on-site production staff the model is considered first, as everyone gets the same picture (SC4, SC5). The higher level of understanding and reassurance was also in action when SC3 had to make a change regarding installation. However, SC3 was not sure that he and the expert had understood themselves correctly over the phone, so they met in person. During this meeting, the BIM was used to make sure that both had the same picture and a decision could be taken on safe grounds.

According to the interviewees in the construction company, some professions have a greater advantage of 3D modeling (PLIT, SC1, SC3). MEP related work due to the restricted spaces, often shared in-between themselves, use the BIM for a better understanding of collaboration between the professions. For SC2, as he is a carpenter from the start, the BIM has helped with the understanding of MEP related work, because of the simplicity of understanding the BIM compared to drawings. Also, pointing on the help of the BIM when considering bushings in the construction, since considering one model and get all the holes is easier than looking at several different drawings for the same area. It has helped with the planning for the MEP workers, as for instance, the plumbing had to be first sometimes, and sometimes another profession had to come first to be able to mount their equipment in the correct spot (SC3, SM1, SM2). In one of the projects visited the first profession assembling their installation in a hallway decided to put up the pendants for all the professions. As they had understood when planning the work that it would be hard for the others to put up the pendants after the first profession had mounted their installations. This realization had been made while looking in the BIM.

Problems have been stumbled upon because of the model, as when SC3 played around within the model to get to know the building better, an issue was observed. It was found that the rooftop was too low in comparison to the required insulation. Because this was observed and solved so early no problems occurred. This problem was stumbled on by accident and curiosity. If the same thing would be happening with

drawings the observer would have to take into consideration several different drawings, lowering the likelihood of finding the issue.

Another observed problem was when the electrician and the driller came into the site office asking why the electrical-ladder had to have an S-shape. The K-drawing had a hole but not the installation drawing. Then, when viewing the BIM they came to the realization that the S-shape was not needed, resulting in less work (SC4).

In one project the BIM was used regularly on both work-preparation meetings and installation meetings. In one of these meetings, a problem regarding the prefab mounting was brought up. Since they were close to another construction building, co-operation had to be made between the two construction teams. It was essential that the model was available in this instance for the two construction teams to understand the situation and solve the problem. In an installation meeting the discussions excelled when contemplating the BIM, as a greater understanding of the different professions was made and therefore an eager to find solutions.

4.3.2 Improvement potential

The expression BIM does not initiate further use anymore, the innovative incentive is gone (PLIT). Therefore, it is now necessary to prove that BIM use is profitable to increase the use of it. Also, in today's construction industry we depend a lot on experience stored in people's brains, the information is locked in, limiting knowledge transfer in the organization.

For the computerization to work and continue to grow within the construction sector, work has to be done regarding standardization (PLIT, SC1, SC3, DL1). With standardization between companies, progress can be made easier. For instance, establish a standard identification number for elements in the BIM. Because, as PLIT mentioned, with established ID numbers for elements models, timetables can be created automatically by the computer instead of manually. This structure is important that it flows through the entire process, including purchasing, planning, production, and maintenance work. Hence, limiting the amount of double work.

A mentioned problem regarding the planning of projects is that the planners often lack knowledge regarding constructability (PLIT, SC1). Therefore, the production personnel involvement is sought after in the planning phase, as they are busy with an ongoing project, and therefore have limited time understanding the drawings nor affect the BIM. An improvement potential is to include more production related information in the model. Scaffolding, crane, logistic planning and the ability to have the construction site layout plan in 3D (SC1, SC2, SM2).

Several of the interviewees (SC2, SC3, SC4) focus on the importance that foremost having a properly well-made model, to begin with. Far from most projects have a

model good enough. Which is also supported by the results from the survey, therefore unavailable to use such tools as quantity takeoff. There are also those who do not know how much they could trust the model (SM1). Problems that have occurred is that the same element does not have the same name in different places in the model (SC2). SC3 that has had a proper BIM to work after pushes for even more information, with the inclusion of LOD350. As he believes that suspension from the roof would be beneficial for planning. This would improve planning and visualization for workers, and the understanding of why some workgroup must go before others.

Connecting to the importance of having good enough BIM to work after is to continually update the model throughout the project. As tendencies of paper drawings being updated but not the BIM has been observed (SC1, SC2, SC3). This has created disbelief in the model.

SC2 believes that the knowledge level required to maneuver in the model is low. With an assigned person, responsible for the BIM use on each project knowledge levels can rise quickly (SC1, SC2, SC3, SM1, SC4, SC5, SM2). This is an idea that was supported by all interviewees. The studied company has started an initiative with so called *digital leaders* in production that has this responsibility regarding technology tools during the production phase. This will benefit the utilization of BIM and other digital tools. Because, when one struggles with a new way of doing a task it is easier to go back to the tried and trusted way, if help is not provided directly, as they do not have time to wait, nor for someone to come and help them a couple of days later. Also, not everybody needs to be advanced in model use. With this in mind, the interface of the software needs to be simpler, eliminating noise from the screen (SC1, SC4). SM1 supports the feeling of there being a lot of different tools available when first entering the program. Therefore, a custom variation of the software, with fewer options would help with the first steps of learning. A kind of production view within the program, including quantity takeoff, collision control, and viewability (SM1, SC4). Also, there are a lot of different programs, which should be compressed into one to help with the initial learning.

When the drawings and the BIM do not show the same thing, the drawings are what you are supposed to build after (SM1). Because it is a legal document. However, as we change the way we distribute information, we need to change the information we make decisions on (PLIT).

In one of the projects, that SC1 spoke about, the electrician had decided not to model in 3D. This was the only profession that did not do this, with the reasoning that their electric cable did not take up any space. However, when having to install several cables in the same space, the electrician used a 100mm plastic tube. Due to that, this was not modeled, they missed the space requirements in the wall for this. Thereby, they had to cut up the floor to fit the tube with cable, in every single apartment, costing the project several thousand Swedish crowns.

During the work with the rebar and foam for the foundation work on a project, a mistake was made. There was only going to be placed foam underneath the rebar on the part with ground pillars, two-thirds of the area approximately. This was shown by a small detail in the drawings, and the model was not so detailed regarding the foundation work that it showed rebar and foam. When the mistake was noticed, the foam had been placed underneath all the rebar. Forcing the personnel to reach through the rebar, carving out as much foam as possible. It was widely considered within the production team that this would have been avoided if visualized within the model. Because of how easy it is to see things in 3D compared to interpret drawings. SC1 had a similar experience, where they had put rebar over a shaft, the model did not include rebar in this project either. The interviewee was certain that this would not have happened if the model had the information.

In SC2's project, the model has been of a low standard. This has contributed to several problems, such as collisions between the different professions. They tried to execute a collision control in the project, but since the holes in the prefab was not modeled, the amount of incorrect collision was unworkable, and misleading. SC2 feel that it is important to include all information regarding the different installation components, for example, the insolation on ventilation pipes. As this takes up quite the space. The low level of detail in the model has sometimes contributed to problems in the construction. Once the holes in the prefabrication were not modeled well enough and therefore some were missed. Another one was that the model did not show the correct amount of walls, which contributed to misbelief and problems in the project towards the BIM. Thus, SM1 states that a higher level of detail needs to be put on the model.

4.3.3 Application of extended model use

In the following chapter results regarding how the BIM can be applied at the construction site is presented. This includes benefits for work environment use, such as safety hazards. The application of the time-table to the BIM is also discussed.

4.3.3.1 Work environment

The BIM can be useful when working with the safety on the construction site, thanks to the visualization tool, dangers and risks can be observed easier (PLIT, SC2, SC5). A lot of accidents on construction sites happen with temporary constructions, these are however usually not included in the BIM. Therefore, including this together with 4D would help the safety work massively. Because of the understanding, the visualization generates. The use of 4D helps as it is easily visible when work is ongoing close to each other, instead of noticing it in the timetable (PLIT). As well as the general visualization benefits (SC2, SC5). With the use of VR glasses and

simulations of accidents, it is believed that the awakening regarding risks can happen before the real accident takes place, which is usually the case (SC5).

With the use of BIM, the cooperation at the workplace has gone up (SC3, SM2). The higher level of understanding has generated a greater feeling of responsibility for the workers, as they understand their importance in the bigger picture (SC3). This had evolved to a greater level if it was by 4D or 5D.

With additional information regarding weight on elements that need lifting, work preparation work can be made to a greater extent (SC1). For instance, when deciding upon how to mount windows, the weight is important.

SC3 has used the model connected to construction site introduction and work preparation work. They have usually taken a bit longer time than regularly. However, it has created a better discussion between the participants, solving problems not thought off before they had happened. As the model generates a quick and good overview. Therefore, using the model may take a longer time. However, as it brings up different questions, and most often solving them, the overall time is lower.

4.3.3.2 4D use in production

With the inclusion of time in the BIM, the amount of information attainable is higher. A big responsibility will fall on those planning, as the timetable is one of the most important things in construction (SM1, DL1). A 2D timetable is hard to understand, and take it all in consideration at once, therefore it makes sense to show it in 3D (SC5, SM2, PLIT). It goes back to converting information, 3D to 2D and back, and the loss of information (PLIT). With a 4D BIM, the information becomes very concrete (SC4). Therefore, it will be easier for people to understand where they should be and how much they should produce. The timetable would be easier to follow with this tool, and therefore the budget of the project would likely follow to (SM1, SC4). Hence, the time spent is one of the critical factors to the budget of the project and one that is discussed the most on the construction site.

With the tool of 4D, it will be easy to do follow-ups regarding the progress, and none will be able to blame tardiness on misunderstandings (SC1, SC4). However, the digital timetable then needs to be worked with daily and constantly updated (SC4). With the constant changes that happen on a construction site, it would be hard to follow the plan step by step. Therefore, it would be most beneficial, according to SC1, to use it as an overview tool to create a consensus view.

With the use of 4D BIM, planning for the different subcontractors would become better (SC2, SC4). Some of the interviewees want the 4D BIM to update from day-to-day and beliefs that this would be the most beneficial (SM1, SC4). But, some believe that an update a week would be enough to start with (SC2). Thus, using it simply to

get a quick overview. When considering worksite with a lack of space the 4D BIM can be very beneficial to visualize storage, transports, and barriers for the public and safety hazards (SC4).

Important to consider when creating the 4D BIM at the start is that the model is separated in the same way as the timetable (DL1). Also matching the ID on the BIM elements to the ID in the timetable, this would give you a good start for the 4D use. The planner has with the help of the 4D BIM been able to inform fellow co-workers of their planning in an easier way. This is how one project mainly have used their 4D BIM, mediate the timetable to the participants in the project (PLIT). By using the 4D BIM during meetings good communication and understanding have been happening. Hence, everybody understands what is discussed. 4D BIM has mainly been seen as a communicative tool, visualizing the different stages and the timetable. A timetable that can be complex and hard becomes a lot easier to understand with visualization. Also, a greater understanding of what processes that occur during the same time in construction. Thus, enabling more safety and logistic planning.

4.3.4 Skepticism

People are afraid of change. The industry is branded by "it was better before". Without knowing the benefits of BIM, one will not want to learn something new when the old way works (SC4). If one does not see their own profit of changing, the human will not do it, because of being selfish. With new things, there is always a scary feeling, as you cannot handle it and maybe does not understand it initially (SM1). Sometimes you have your routines and feel that it is a quicker way to do it. However, then if you leave one construction site, the information goes with you. One way to dissolve the skepticism according to SM1 is to use the tool more, make it a regular routine.

As a supervisor, the general perception is that office work is worth less than work on site (SC4). The reality is not the same nowadays as it was 30 years ago, things change. The digital is the future, also within construction. Therefore, we need to try and change, and those who do not will fall behind. Hence, the older generation's superiority, considering building houses, might fall a bit due to the new technology tools available. With this change, you remove a part of one's personality, one that is used to be a focal point in decisions (SC3). Because the information is so much easier to interpret and make decisions off. Therefore, the skepticism is more based on the change of power than trust in the model. Compared to the overall results from the survey that showed that most lack a trust in the model and therefore are skeptical to it. The general person wants to have the knowledge and be considered important. There is a change of power if a young person suddenly has more knowledge than an older more experienced (SC3, SC4). If the digitalization continues the older people know that they will fall in importance. Some have a hard time with having someone new telling them that they can do things in a smarter more efficient way. It is worth

noticing that some of the interviewees believe that there is no skepticism towards BIM use in the construction industry (SC1, SC2).

5 Discussion

In this chapter, the findings in the literature study will be compared to the results from the interviews and the survey. The author will also present his own thought in certain areas.

5.1 BIM use today

The standout when considering the use of BIM in the production phase is visualization, making sure that everyone sees the same thing instead of interpreting drawings. As several of the interviews mentioned, and supported by Chelson's (2010) findings regarding the lower amount of RFI, the BIM helps with understanding the project. The step of converting 2D drawings to a mental 3D visualization is removed from the process. With the benefits being it is quicker and more secure, that the visualization is the same by the participating persons. Merschbrock & Nordahl-Rolfsen and Malmkvist pushed on the help from the BIM when trying to understand complex structures with the buildings and SM2 even admitted that he would not have been able to take responsibility for the installation work if he did not have BIM. This is also supported by the research by Murvold et al. (2016) and Svalestuen et al. (2017) and by the results from the survey were most people used the BIM for visualization purposes, both for those who deemed themselves bad at handling the BIM as well as those who said they were good. The high use of visualization might be due to that visual communication excels audio communication and is necessary for complex projects (Wileman1993) (Svalestuen, Knotten, Lædre, Drevland, & Lohne, 2017). To increase the visualization possibilities 4D BIM can be used. It has been shown that 4D BIM has decreased project time, reduced risk hazards and helped with logistics (Sediqi, 2018) (MWH Treatment, 2017). The skillset needed is not higher than to use BIM initially, focusing on moving around in the model, visualizing information. The increase in work is located with the planning team and is front heavy. SC3 thought of the possibilities to work with 4D BIM as another step in helping with understanding and planning, as supported by the findings of Sediqi (2018). There is also a belief that another resource to work with 4D is not necessary if it is implemented, as the time saved from other tasks will generate enough free time (SC3). The general belief from the interviewees is that 4D BIM would increase their work efficiency significantly and 76 % of the respondents on the survey wants to work with 4D BIM or higher. The results also show that visualization and planning are what the respondents mainly wants to use 4D for.

With BIM, information can be reached instantly. Bound to that the drawings are detailed in a specific manner to express this information. Since the BIM contains the entire model one can choose from which angle and with what information one wants to observe. Construction workers wait 35 % of their time due to lack of information, waiting for material and waiting for other professions (Chelson, 2010). These are areas where BIM can help according to the result from this study. Regarding the lack

of information, with BIM information can be stored in one place. None-depending on how the architecture has developed the drawings as the model can be twisted, turned and scaled as pleased. Therefore, the information is there if the handler knows how to use the BIM, the potential waiting time is therefore lower. The BIM can also affect the problem waiting for material. It is not specified why the wait has occurred, late transport or lack of order for instance. With BIM a higher level of precision of ordered material can be held due to tools such as quantity takeoff. This tool, and with the help of sectioning, gives the opportunity to have higher assurance on material orders, for specific stages of the project. As mentioned by many of the interviewees the BIM helps with planning between different professions, as they understand the other professions work better. Usually, only taking in information from their own drawings now they receive information from all professions in one model, enabling better planning for the professions and their progression. (Murvold, Vestermo, Svalestuen, Lohne, & Lædre, 2016). Malmkvist (2013) also stated from their study of the case Röforsbron that BIM increased planning and decreased re-work. The planning of progression between different professions is also one of those tools that most use on-site, ranking joint second with 43 %.

5.2 Improvements

In the following chapters discussion will be held in regards to improvements to use BIM more and better. The areas of improvement differentiates and are therefore presented in different subchapters.

5.2.1 Increase the use of the BIM

To increase the use of BIM in everyday work the biggest need is to show the value of using the process, as the innovative incitement is reached (Love & Wang, 2012). From the survey, there is the support that concrete evidence would increase the model used, with almost 20 % requesting it. It falls behind the two results of needing more knowledge of how to use it, as well as to have more time. In my opinion, those two reasons are intervened. The BIM can often help with reducing the time needed on some tasks if the knowledge exists. Otherwise, the lack of time will continue to be a problem. The three biggest reasons to use the model more are based on the same core reason, understanding the benefits of model use. If you understand the benefits you will have concrete evidence on why it makes your work easier. Thereby, giving yourself more time with the model and gaining more knowledge. However, that has to be initiated by some factors affecting either of the reasons. Walasek and Barszcz (2017) believed in providing more results that showed the benefits. However, 37 % in the survey said that they used BIM due to improving themselves, an innovative incitement. Hence, the result of 97 % wanted more education within model use. In the study done by Brantisa and Norberg (2018), they found that 87 % of their respondents wanted more education in BIM usage. Both results reinforce that construction personnel wants to use BIM more. When analyzing was made on those who had training in model use, the average skill level only raised from 2.62 to 2.85 on a 5-graded scale, this could be considered worryingly low. With this in mind the conclusion that the education has been poor can be drawn. However, this might not be

the case. As the participants in the study might have gone into the education only knowing how to orientate oneself in the model, and then being presented with all other tools, such as quality takeoff and collision control. So the training might have taught the participants several things that have raised their skill, but their perception of a 5 on the scale could also have shifted. One without training might consider a 5 as one that can orientate in the model.

The studied construction company has started a process of implementing a digital leader in construction for all projects. All interviewees are positive to this initiative and believe that it will help with the BIM work on the construction sites. With the assigned resources they will be able to help on the day-to-day basis with digital work. The biggest challenge to cross for BIM to be implemented and used by all is for people to see the benefits of it. From the interviews, there is thought that if it does not work initially then one will go back to the tried and trusted way of doing things, stopping the evolution and growth of the industry. With an allocated resource on the site, they could receive instant help with these problems. Solving the issues instead of pushing it to the side for later. The author believe that this also would help with the general perception of BIM, mainly the view on BIM by the older generation. The overall view it as another digital tool, something new they have to learn and struggles. With the assigned digital resource next to them and with instant help if issues arise, they will hopefully be able to see the benefits and advantages of the tool rather than the struggles. Also, helping with the change of role for the more experienced workers. Another way to increase BIM use on site is to allocate time for learning. With allocated time the reason of doing it the old way due to not having time is obsolete. Practice is essential to learn new skills, not only education. With allocated time and assigned *digital leaders* in the production team, everybody should be able to reach a beneficial level of BIM use. This correlates with the responds on the survey, where more time was a big reason for why they did not use the model as much as they want.

5.2.2 Trust in the BIM

For BIM to be used more by site personnel an increase of trust needs to be put in the model. Often presented as something to look at but not base decisions on, BIM does not start off well (Bedrick & Vandezande, 2018). If the model is only presented as a tool to help understand, but with drawings deciding double work is happening. Therefore, it would be interesting to complete a project with the BIM certified as a deciding document/software model. A problem that could occur is to identify changes in revision since model changes are harder to identify compared to changes in separate drawings. To identify the changes between updates in the BIM the function Model Comparison in Solibri can be used for instance, where models are compared and changes are presented. Eliminating a frustrating search of changes for personnel. By using BIM as a certified construction document the importance and trust of the model will rise. Attempting this for a smaller project might be beneficial to receive quick feedback and results, to see if is a good idea or not.

5.2.3 Detail level of the BIM

From the standpoint that the BIM shall be beneficial on the construction site, a Level of Development of 300 is needed. Encouraged by BIMForum (2017) a level of trust for the BIM is needed for the workers to use it. Otherwise, work will only be multiplied for them. Without a LOD300, no real decision can be made upon the model and therefore only generate more questions when considering the model as it will not match the drawings, creating a distrust with the model. LOD350 is an increase in detail of the BIM, which can be beneficial for the on-site production. It includes connections and relations between different elements. If this information was in the BIM, it would greatly help the inexperienced in determining attachments. Waste could also be reduced as the quantity takeoff tool would give an exact amount. However, this puts an even greater responsibility on the person developing the BIM. As with the project SM2 is conducting, a LOD350 BIM would only benefit the project. Because of the high density of installations. These projects with high-density installation, have the most benefit from a LOD350 BIM. But, if trust and use cannot be put in the model then it can be considered only a cost. With the results from the survey in mind, the construction company needs to become better in communicating the quality of the model. This and the information of how much you can trust it is essential to make it generate value instead of just absorbing time and money. A distrustful model will only generate double-work and problems. Compared to Areno's view that BIM lowers the stress levels on a project due to the accessible information.

When considering what is supposed to be included in the model there are improvements to be made. The focus usually lies on the detail level of the model, as the LOD is important. However, the construction company should start implementing worksite items in the BIM and not only the house. As the construction personnel is there before and during the house is built, not after. Therefore, the information surrounding the house is as important as the house itself. With the introduction of this information, several improvements can be made regarding the safety and logistic works on-site. Today enough focus is not put on the surrounding impacts on the house. With the implementation of adding on-site items to the model, better planning can be made and visual understanding of hazards (NYC Buildings, 2013).

5.3 Challenges

With the help of BIM and the proved benefits of understanding and visualization, younger people have an easier time to get into the knowledge of the industry. As drawings can be considered their own language to interpret, as mentioned by PLIT. With BIM there is an availability to scale down the need of understanding drawings, as one gets a clear picture from the BIM directly. However, the detail level of the drawings is important in some cases. Therefore, the ultimate is to combine the use of BIM and drawings. Younger people also have the advantage of having an easier time with IT tools, as they have grown up with it. This, as mentioned by SC3 and SC4,

begins a switch of power inside the organization. The initiating process of getting up to speed is shorter, and in some areas, the young exceeds the experienced. They might have an easier time to maneuver in the BIM. When then the construction workers start to request BIM to access information they often ask the younger ones as they tend to have better knowledge with the tool. Therefore, the more experienced are not central for information access, as much as before. Their hard fought-role has changed, and they need to change. Their knowledge of how to build is still extremely important, and they can now describe it in an even better way, if they learn how to maneuver in the BIM. As Chelson (2010) found that those with CAD experience initially fell behind in productivity, but after the start-up period excelled others, question is will the older personnel excel once they are up to speed. PLIT and SC1 saw the benefits of the more experienced to use BIM, as they were able to see more, describe and explain better. All signs point towards this, once they accept BIM, their change of role and learn it. Information has tendencies from before to be stored in paper drawings and inside experienced personnel brains. Now, it is more digital and understandable to all, helping with bridging the knowledge gap between generations.

Lindström (2013) stated that doing quantity takeoffs from BIM was hard. This could be considered the last step of learning to use the model. From investigating what the superior users used the model for the biggest change compared to the rest was their use of quantity takeoff. The quantities estimated have proven to be more precise, conclude in less waste (Malmkvist, 2013). Quantity takeoff is the function the respondents want to use the model for the most. Creating a pressure on both what should be taught as well as to the level of detail on the model. This correlates with the results regarding why they cannot use the model as they like, as seen in chart 16. The ITO's developed by the company was not known to the interviewees, except for SC2 who had been involved in the making of them. Hence, simple information sharing to the site personnel could decrease the amount of education needed. Only having to provide an understanding of how to analyze the data. SC1 also gave an example of when a quantity takeoff saved them considering the amount of windows to order.

Paper drawings have been the main information distribution tool for construction for a long time. However, as the way of communication change, the way of information sharing needs to change as well. BIM contains the necessary information, if well-developed, in one place. When using paper drawings, you might need to take several different ones in consideration to get the complete picture, this makes paper drawings less efficient than using BIM. Paper drawings have therefore shown to affect the time negatively on processes (Luo & Xu, 2014). However, there is not a belief in that paper drawings can be eliminated from production by the interviewees. The view is that drawings and the BIM complement each other. By producing your own production drawings, directly from the model, you can eliminate noise (van Berlo & Natrop, 2014). When noise exists in drawings unnecessary questions often arise (Merschbrock & Nordahl-Rolfsen, 2016). Unfortunately, production drawings is a function not used very much in production. It can be argued that this function of developing drawings is

most beneficial when the project is the most stressful. Since this is the time when extra labor is brought in to produce more, not being familiar with the construction site and only there for a short time. Providing drawings with only the information required to execute the task will then be beneficial for the situation. The biggest obstacle for this to work is the knowledge of the site managers. They need to have both knowledge of the technology and the requirements from the workers (van Berlo & Natrop, 2014). It has been assumed from the research by van Berlo and Natrop (2014) that the provided drawings need to be done before the workers need them. However, there is a benefit of letting the workers be involved when the drawing is produced, as it will create a feeling of co-operation as well as improve the sharing of knowledge.

If progression is to be made regarding digitalization within the company standardizations need to be established. For instance, identification of elements in BIM named the same across all projects. To be able to develop appropriate ITO´s, and an easy way to interpret the information from the ITO´s, since doing an ITO and using the information is not the same thing.

6 Conclusion

The studied construction company has good indications with their BIM work. Focus has lately been introduced on the production aspects, from mainly being a project planning tool. The work with implementing a digital leader in each production team seems beneficial from all aspects, it was strongly supported by the interviewees and would help with the initial struggles some might have.

The main purpose of using BIM today is visualization. With BIM being modeled in 3D all get an instant understanding of how things are to be, instead of trying to interpret different drawings and combining them in your mind, this brings down the required experience to understand drawings. Although, experience from how to build still exist. However, the BIM helps with better communication between production personnel and labors, enabling collaboration and understanding of each other's profession.

By examining internal documents of the construction company it is clear that they aim for a well-made BIM, responding to somewhat close to a LOD300. This is the cut off for believing that the BIM shall be beneficial for the production team. As with a lower quality BIM, it is only for viewing purposes, not basing decisions upon. A LOD300 unlocks several tools not available in lower quality, such as quantity takeoff, decision making and collision controls. However, there are still some doubts within the production personnel that the BIM is off to low quality. The author believes this is mainly due to a lack of communication between the planners and the production team. The quality should be clearly communicated and the production personnel needs to have knowledge of what they can do with certain LOD's. It is also important that the BIM is continuously updated throughout the project.

The construction company faces a struggle with getting their more experienced personnel to use BIM, as they already have a reliant working way of doing things. With getting them up to speed the *digital leaders* in the production teams might be a big help. But, they must accept a change of role and understand that they can develop themselves with the help of BIM. With the help of BIM, their knowledge transfer can excel as the tool can help with describing their solutions for different building problems.

6.1 Answering the research questions

In the following chapter I will answer the research questions for the master thesis.

What are the main purposes of using BIM in production?
To create a clear picture for everybody involved in the project. The BIM enables that everybody involved can visualize what is being built without any prerequisite drawing knowledge. Quantity takeoff and collision control are tools to make ensured decisions on.

How is BIM used by the site personnel today, and what do they want to use it for in the future?
The results from the survey and the interviews show that BIM is mainly used for visualization purposes today, with some using tools such as quantity takeoff and collision control. The results also show an interest in working with a higher degree of BIM, such as 4D and 5D. With 4D being the most requested and where benefits are understood. With 4D the main purposes would still be visualization, as building flows and safety hazards can be visualized better.

What knowledge is needed for BIM to be beneficial in production?
For the BIM to have a purpose in production, the skillset of the workers has to be good maneuver and visualization skills. As visualization is the main purpose of BIM use, no more knowledge is necessary to be beneficial. The BIM has to be of LOD300 or higher for it to be able to contribute, as it otherwise only will raise questions, since information from the BIM and the drawings might not correlate.

What are the superior users using BIM for compared to the rest?
What differentiates the superior users are their use of tools such as quantity takeoff and collision control. Especially quantity takeoff is one of those tools that many want to use but almost only the superior users can use. The superior users also tend to have a greater trust in the BIM, indicating that knowledge leads to confidence.

6.2 Suggestions for improvement

Considering the research made for this thesis, of the construction company, literature study and the quantitative and qualitative results some recommendations of focus regarding model use for the company has come up.

- Communicate the quality of the model to the production personnel.
- Keep on pushing with associated *digital leaders* in the production teams.
- Teach everyone the basics of visualization and examples of situations to use it in.
- Update the model ongoing in the project along with changes for installations, architectural and so on.

- Include site objectives in the model, not only the house. Such as cranes, scaffolding and containers.

With these suggestions I believe that the studied construction company can excel even more in their work with BIM. The eagerness of wanting to use more BIM in the construction company is clearly visible.

6.3 Future research

After conducting this master thesis some more interesting research has been detected. Due to the size and scope of the thesis, this has not been researched. However, I recommend further research within the areas. To either add on to the work of this thesis or conduct a more specialized one.

- How and what data that are to be stored and keep track for making it possible for AI to create timetables for projects. With only the 3D model as a basis.
- Is it better to conduct pilot projects on smaller projects rather than big?
- Further research regarding the actual outcome of using 4D and 5D BIM in construction.

7 References

Areno, L., & Mohammadi, A. (den 27 November 2018). BIMpodden: Episod 12: Skanska - Roller och verktyg. Stockholm, Sverige.

Bedrick, J., & Vandezande, J. (2018). Defining Level of Development. *Defining Level of Development - Specifying BIM Deliverables*. USA: BIMForum. Hämtat från Digitala Vetenskapliga.

Berglund, L., Johansson, J., Johansson, M., Nygren, M., Rask, K., Samuelson, B., & Stenberg, M. (2017). *Risker och säkerhetsarbete i byggbranschen - En kunskapssammanställning baserad på internationell forskning.* Luleå, Sverige: Arbetsmiljöverket.

Bertram, I. (2009). *Hur ser en bra enkät ut? - En kritisk granskning av befintliga frågeformulär.* Lund: Avd för Arbets- och miljömedicin, Lunds Universitet.

BIMForum. (2017). *Level of Development Specification Guide.* BIMForum.

Brantisa, E., & Norberg, R. (2018). *BIM Implementation in the Production Phase of the Construction Process - Site Management Teams' Knowledge, Attitude and Needs.* Chalmers University of Technology - Department of Arch.

Chelson, D. E. (2010). *The effects of building information modeling on construction site productivity.*

Cousins, S. (2017). Total BIM: How Stockholm´s £1bn urban transformation project is going 100% digital. *Construction Research and Innovation*, 34-40.

Englund, E., & Grönlund, M. (2018). *Current Legal Problems and Risks with BIM in the Swedish AEC Industry.* Stockholm: Royal Institute of Technology - Department of Real Estate and Construction Management.

EU BIM Task Group. (2017). *Handbook for the introduction of Building Information Modelling by teh European Public Sector.* EU BIM Task Group.

Fellows, R. F., & Liu, A. M. (2015). *Research Methods for Construction.* John Wiley & Sons, Incorporated.

Hagman, G., Mohammadi, A., & Wibeck, L. (den 11 December 2018). BIMpodden: Episod 13: Skanska - Lyckad organisation för en digital framtid. Stockholm, Sverige.

Hesselgard, C., & Mohammadi, A. (den 13 November 2018). BIMpodden: Episod 11: Skanska - Förändring över tid. Stockholm, Sverige.

Jamshed, S. (2014). Qualitative research method-interviewing and observation. *Journal of Basic and Clinical Pharmacy*, 87-88.

Lindström, A. (2013). *Model-based Quantity Takeoff in Production.* Göteborg, Sweden: Chalmers University of Technology.

Love, P. E., & Wang, X. (2012). BIM + AR: Onsite information sharing and communication via advanced visualization. *Proceedings of the 2012 IEEE 16th International Conference on Computer Supported Cooperative Work in Design (CSCWD).* Wuhan, China: IEEE.

Luo, H., & Xu, S. (2014). The Information-Related Time Loss on Construction Sites: A Case Study on Two Sites. *International Journal of Advanced Robotic Systems*.

Malmkvist, M. (2013). *BIM i projekt Röforsbron.* Eskilstuna: Trafikverket.

Merschbrock, C., & Nordahl-Rolfsen, C. (2016). BIM technology acceptance among reinfrocement workers - The case of Oslo Airport´s terminal 2. *Journal of Information technology in Construction*, 1-12.

Murvold, V., Vestermo, A., Svalestuen, F., Lohne, J., & Lædre, O. (2016). Experiences from the use of BIM-stations. *Proc. 24th Ann. Conf. of the int´l. Group of Lean Construction* (ss. 23-32). Boston, MA, USA: IGLC.

MWH Treatment. (2017). *Minworth THP - MWHT submitting this project in competition to demonstrate 4D planning and delivery capability.* 2017 Digital Construction Rewards.

NYC Buildings. (2013). *Building Information Modeling Site Safety Submission Guidelines and Standards (BIM Manual).* NYC, USA: NYC Buildings.

Sediqi, M. (2018). *4D BIM adoption - The incentives for and barriers to 4D BIM adoption within the Swedish Construction Companies.* Stockholm, Sweden: Royal institute of technology.

Sociology Harvard. (den 26 November 2018). *Harvard education.* Hämtat från Some Strategies for Developing Interview Guides: https://sociology.fas.harvard.edu/files/sociology/files/interview_strategies.pdf

Solibri Inc. (den 7 November 2018). *Solibri*. Hämtat från solibri.com: https://www.solibri.com/bim-ifc

Stewart, N. C. (2011). *Research Ethics for Scientists: A Companion for Students.* John Wiley & Sons, Incorporated.

Svalestuen, F., Knotten, V., Lædre, O., Drevland, F., & Lohne, J. (2017). Using Building Information Model (BIM) devices to improve information flow and collaboration on construction sites. *Journal of Information Technology in Construction*, 204-219.

Svensson, P. (den 25 Februari 2015). Kvalitativ och kvantitativ undersökningsmetodik. Göteborg, Västra Götalands län, Sverige: Chalmers.

Walasek, D., & Barszcz, A. (2017). Analysis of the adoption rate f Building Information Modeling [BIM] and its Return on Investment [ROI]. *Procedia Engineering*, 1227-1234.

van Berlo, L. A., & Natrop, M. (2014). BIM on the construction site - providing hidden information on task specific drawings. *Journal of Information Technology in Construction*, 97-106.

Wileman, R. E. (1993). *Visual Communicating.* Educational technology.

Figur References

Abstract

Use of the 3D modell in production

This survey is for you in production to give feedback on how you use the model. To improve the work with it and put support in areas needed. First and foremost to get the information what YOU think. The survey is anonymous.

Age *

- 20-30
- 30-40
- 40-50
- 50+

Work title *

- Site manager
- Supervisor
- Project engineer
- Other...

Education level *

- ○ Upper secondary school
- ○ Work preparation school
- ○ 3 year university
- ○ 5 year university

Work experience construction *

- ○ 0-2 years
- ○ 2-5 years
- ○ 5-15 years
- ○ 15-30 years
- ○ 30+ years

What is BIM for you?

Short answer text

In what projects are BIM used? *

- [ ] All projects
- [ ] Technical advanced projects
- [ ] Complicated projects
- [ ] Research projects

What is BIM for you?

- ( ) A 3D model
- ( ) A computer tool
- ( ) A process to increase communication
- ( ) To do stuff in the computer

How much time do you spend in the model each week?

- [ ] Less than 2 hours
- [ ] 2-4 hours
- [ ] 4-8 hours
- [ ] 8-16 hours
- [ ] More than 16 hours

How good are you at using the model? *

	1	2	3	4	5	
Bad	( )	( )	( )	( )	( )	Good

Have you had any training/education in model use? *

- ○ No
- ○ yes, within the last year
- ○ yes, within the last 3 years
- ○ Yes, more than 3 years ago

Would you like more education in model use?

- ○ Yes
- ○ No

What software have you used to check in the model?

- ☐ Solibri
- ☐ Navisworks
- ☐ BIM360 Glue
- ☐ Tekla BIMsight

What makes you use the model? *

- [ ] The management say that we shall use it
- [ ] Innovative incitament / to improve myself
- [ ] It makes work easier
- [ ] There are financial gains to be made
- [ ] We have decided to use the model in production
- [ ] I do not use the model

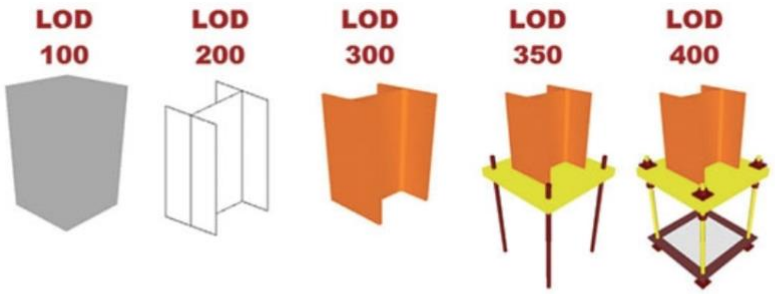
How do you want to access the model? *

- ( ) In the computer
- ( ) In the phone
- ( ) On a tablet
- ( ) Screens in public areas
- ( ) BIM-stations on-site
- ( ) I do not want a model

Do you work after the model, or do you only see it as an compliment to the drawings?

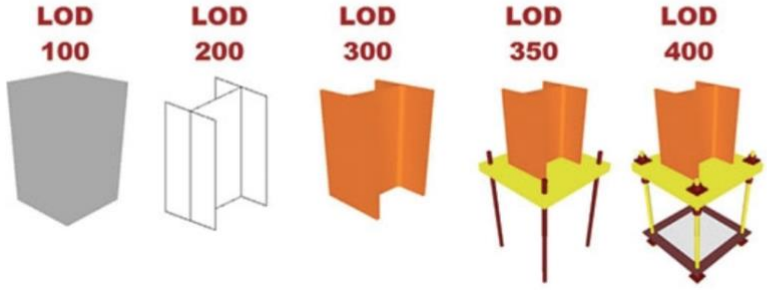
- ( ) Yes, I work after the model
- ( ) No, I always use the model
- ( ) In some cases I only use the model

How good was the quality of the last model you used? *



- [ ] LOD 100 - objects in the model occupies a space. Size, placement and distances are not correct
- [ ] LOD 200 - objects in the model looks like the real ones. Distances, placement and size are not correct.
- [ ] LOD 300 - objects in the model look like the real ones. Size, distances and placement can be used from the model.
- [ ] LOD 350 - objects in the model has the correct placing, information and size. Information about connection between...
- [ ] LOD 400 - objects in the model are so well modelled that pre-fabrication from them.
- [ ] I do not know

How good quality do you want of the model to be able to use it as good as possible? *



- [ ] LOD 100 - objects in the model occupies a space. Size, placement and distances are not correct
- [ ] LOD 200 - objects in the model looks like the real ones. Distances, placement and size are not correct.
- [ ] LOD 300 - objects in the model look like the real ones. Size, distances and placement can be used from the model.
- [ ] LOD 350 - objects in the model has the correct placing, information and size. Information about connection between...
- [ ] LOD 400 - objects in the model are so well modelled that pre-fabrication from them.

What had made you use the model more? *

- ○ Concrete evidence that it makes my work easier/better.
- ○ More knowledge in model use
- ○ More time
- ○ That management really believes in it
- ○ I already use the model as much as possible

In what ways has model use changed the way you work? *

- ☐ It has made it easier to get a full sized picture of the project
- ☐ Some work tasks that have taken a lot of time now takes less
- ☐ More dubble work. Since, I can not trust the model
- ☐ Helped with organizing between different work professions
- ☐ It has changed the way i calculate the amount of material
- ☐ Work site plans has become clearer
- ☐ I do not need to ask the architect as much since it is easier to understand from the model
- ☐ It has not affected my work significantly
- ☐ Other...

I use the model to do the following things

- [ ] Work preparation
- [ ] Planning
- [ ] Visualization
- [ ] Quantity takeoff
- [ ] Information accessability
- [ ] Co-ordination between work professions
- [ ] Collision controls
- [ ] Logistic planning
- [ ] Production drawings
- [ ] Links between model and documents
- [ ] I do not use the model
- [ ] Other...

I want to use the model to do the following things.

- ○ Work preparation
- ○ Planning
- ○ Visualization
- ○ Quantity takeoff
- ○ Information accessability
- ○ Co-ordination between work professions
- ○ Collision controls
- ○ Logistic planning
- ○ Production drawings
- ○ Links between model and document
- ○ Other...

If there is a difference between what you can do and what you want to do it is because...

- ○ The model is not good enough
- ○ I lack the knowledge to do it
- ○ It is easier to do it the old way than to learn a new
- ○ I do not have the time

I am interested to work with

- ○ 2D drawings
- ○ 3D models
- ○ 4D models (Time schedule is connected to the model)
- ○ 5D models (Price/costs are connected to the model)

If I had a 4D/5D model I would use it to...

- ○ Better visualization posibilities for myself
- ○ Be able to better plan the different work professions progression
- ○ Logistic planning
- ○ A cost overview
- ○ Cost feedback
- ○ Follow-up on time consumed for different tasks
- ○ Other...

Other thoughts

Long answer text

Thanks for answering!

Hopefully this will help with making your model use better/easier/more effective.