Integration of BIM in the construction phase

- A study of a Swedish construction project based on interviews

Master of Science Thesis in the Master's Programme Design and Construction Project Management

EBBA BIRGING & NILLA LINDFORS

Department of Civil and Environmental Engineering
Division of Construction management
CHALMERS UNIVERSITY OF TECHNOLOGY
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ABSTRACT

Building Information Modeling (BIM) is a combination of different technologies and ways to organise construction projects. The intensions of BIM are to develop and increase the work capacity amongst and across the different actors in a construction project, thus increase the collaboration. Other benefits by implementing BIM are increased productivity and quality within all stages in a construction project: design, construction and maintenance. The purpose of this report is to investigate how BIM can make the construction phase more effective and optimised, by transferring the BIM information from the design phase into the production phase. This report is a qualitative study and is based on a literature review, a case and interviews. The interviews, which were semi structured, were conducted with different disciplines in the construction phase. Lyckholms is the studied case in this report. This is a new office building designed and constructed by Peab. The results show that the general knowledge among the workers, regarding BIM, is low, but the attitude towards new technology and the existing 3D-model is positive. The main finding by integrating BIM is the possibility to extract section drawings from the 3D-model and the possibility to let the workers decide which particular sections they need. In the traditional way, getting the supplementary section drawings is both time consuming and leads to additional costs. Another finding is that using a 3D-model at the construction site, for visualisation, facilitates the disciplines work through creating a common base for discussion and problem solving, hence creating a team spirit. This indicates a change from a drawing based construction phase to a model based, where the model is the main provider of information. One recommendation is that focus should be on how the already existing information, in the 3D-model, could be accessed rather than on what additional information is needed.

Key words: BIM, integration, construction phase, communication, Level of Detail, LOD

Integrering av BIM i produktionsfasen
- En studie av ett svenskt byggprojekt baserat på intervjuer

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SAMMANFATTNING

Byggnadsinformationsmodellering (BIM) är en kombination av olika tekniker och sätt att organisera byggprojekt. Intentionen med BIM är att utveckla och öka arbetskapaciteten inom och mellan de olika yrkesgrupperna, således öka samarbetet. Andra fördelar genom att integrera BIM är ökad produktivitet och kvalitet inom alla leden i ett byggprojekt, så som projektering, produktion samt förvaltning. Syftet med denna rapport är att undersöka huruvida BIM kan göra produktionsfasen mer effektiv och optimerad genom att överföra BIM-informationen från projektering till produktion. Rapporten är en kvalitativ studie och är baserad på en litteraturstudie, ett specifikt projekt samt intervjuer. Intervjuerna var semistrukturerade och utfördes med de olika yrkesgrupperna i produktionsfasen. Lyckholms är det utvalda projektet, vilket är en nybyggnation av kontorslokaler, som projekterats och producerats av Peab. Resultaten visar på att den generella kunskapen, om BIM, bland yrkesarbetarna är låg, men att attityden till ny teknik och den existerande 3D-modellen är positiv. Den största fördelen med att integrera BIM, visade sig vara möjligheten att extrahera sektionsritningar från 3D-modellen och möjligheten att yrkesarbetarna själva kan välja ut vilka sektioner de behöver. I det traditionella sättet att arbeta är det både tidskrävande och kostsamt att framställa kompletterande sektionsritningar. En annan fördel med att nyttja en 3D-modell är att det underlättar yrkesgruppernas arbete genom att skapa en gemensam plattform för diskussion och problemlösning, där igenom skapa lagkänsla. Detta indikerar en förändring från en ritningsbaserad produktionsfas till en modellbaserad, där modellen är den huvudsakliga informationsbäraren. En rekommendation är att mer fokus läggs på tillgängligheten av den redan existerande informationen, i 3D-modellen, istället för att fokusera på tillägg av ytterligare information.

Nyckelord: BIM, intergrering, produktionsfas, kommunikation, Level of Detail, LOD

Contents

Preface

This Master of Science thesis was conducted at the Department of Civil and Environmental Engineering at the Division of Construction Management. This thesis completes our studies at the Master's Programme Design and Construction Project Management at Chalmers University of Technology. It has been carried out at Peab in Göteborg during the spring of 2014.

We would like to thank everyone who has been involved in this thesis, for support and encouragement throughout the whole process. We would like to thank our supervisor at Chalmers University of Technology, Mattias Roupé, for help with academic issues and support. A special thanks to our supervisor at Peab, Roger Andersson, for guidance, continuous feedback and commitment throughout the process. We would also like to thank all interviewees for taking their time and sharing their thoughts.

Göteborg, May 2014

Ebba Birging   Nilla Lindfors

List of abbreviations

AEC	Architecture Engineering and Construction
BIM	Building Information Modeling
CAD	Computer Aided Design
CTO	Chief Technology Officer
LOD	Level of Detail

English – Swedish dictionary

Architectural and system plans	Systemhandlingar
Client	Byggherre
Construction documents	Bygghandlingar
Construction site	Byggarbetsplats
Coordinated drawings	Samplottsritningar
Design	Projektering
Discipline	Yrkesgrupp
Foreman	Underentreprenörers arbetsledare
Intranet	Lokalt nätverk
Management team	Arbetsledning
Overview drawing	Översiktsritning
Plumbing	VVS
Schedule	Tidplan
Site office	Platskontor
Supervisor	Arbetsledare
Variations	ÄTA-arbeten

1 Introduction

1.1 Background

Building Information Modeling (BIM) is a combination of different technologies and ways to organise a construction project (Miettinen & Paavola, 2014). The intensions of BIM are to develop and increase the work capacity amongst and across the different actors in a construction project, thus increase the collaboration. Other benefits by implementing BIM are increased productivity and quality of all stages in a construction project, design, construction and maintenance. How the result will turn out, by using BIM in a project, depends on many different factors such as the size of the project and the level of the team members' knowledge concerning BIM. The success of BIM will also depend on how well the communication works within the team but also other organisational external factors (Barlish & Sullivan, 2012).

There are the following phases in a construction project: design phase, preconstruction phase, construction phase and operation phase (Jongeling, 2008). One benefit by using BIM in the design phase is the major time savings in the later stages of the phase. As displayed in figure 1, BIM requires a larger amount of effort in the beginning of a project, but is continuously almost the same throughout the project. The traditional way have more peaks especially in the later stages of the phase, which is time consuming.

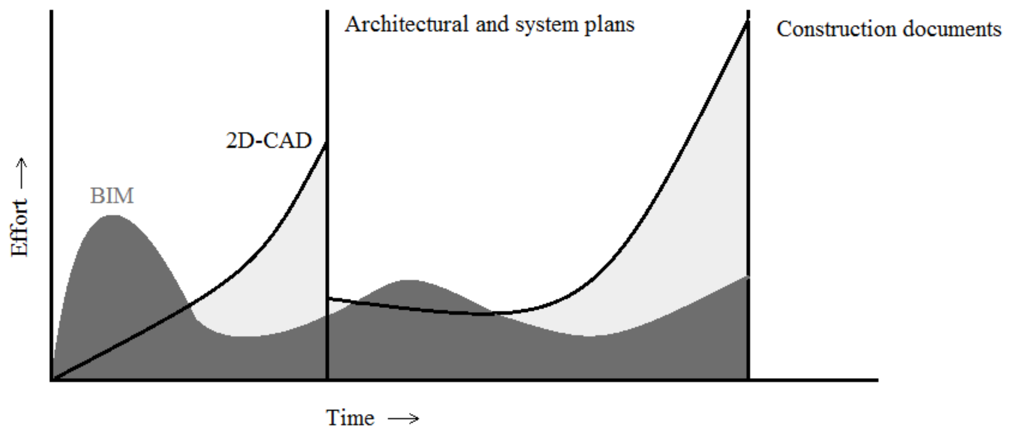


Figure 1: The amount of effort in a project and when it is needed, BIM compared to 2D-CAD, developed from Jongeling (2008).

The traditional way to plan and work in the construction phase is by using 2D-drawings and related documents and gantt charts (Jongeling, 2008). All documents and drawings from the different disciplines need to be compiled and coordinated. Usually the design phase is not finished when the construction phase begins, which makes both phases much more complicated, since all decisions are not made. This situation often leads to problems in the drawings and their related documents, which the workers need to solve at the construction site and this takes time, costs money and can affect the quality. It is most common that BIM is used in the design and preconstruction phase and very little in the construction and operational phases (Eadie, et al., 2013; Goedert & Meadati, 2008). This is also the situation at Peab. The company is constructing a new office building in the central part of Göteborg on the grounds where an old brewery called Lyckholms was situated, hence the project is called Lyckholms. The client of this building is Peab's property development construction area and some of the office areas will be occupied of Peab themselves. This construction project became the case of this report, since this is a project where BIM was used during the design phase. Peab have clearly stated that their overall goal is not to "work with BIM", but instead use BIM as a tool to increase efficiency in a construction project.

There is little and almost no integration of BIM in Peab's overall construction phases, but Peab's vision is to test their knowledge of BIM in the Lyckholms project, which leads to the purpose of this report.

1.2 Purpose

The purpose is to investigate how BIM can make the construction phase more effective and optimised, by transferring BIM information from the design phase into the production phase.

1.3 Objectives

The objective is to investigate the general knowledge of BIM amongst workers at the construction site and to identify the necessary information, which must be included in the BIM model, to make it useful. The identification should support the development of BIM guidelines for the production phase.

1.4 Research Questions

The main focus of the report is on the following questions.

- What is the general knowledge, concerning BIM, among workers in the production phase?

- To what extent can, different disciplines at a construction site, use the information in a BIM model and what specific information is needed, according to the different disciplines?

- What are the obstacles when using BIM in the construction phase and what barriers must be conquered to enable a further development of BIM guidelines, to make BIM more suitable for the construction phase?

1.5 Limitations

In this report the primarily focus is BIM in the construction phase. Peab's new office building, Lyckholms, was used as a case study and since this project only includes a new building, focus has been on questions concerning the use of BIM in new construction projects. When the master's thesis started the project Lyckholms had reached the construction phase and a limitation was to only focus on that specific phase. Another reason for focusing on the construction phase is that Peab already uses BIM in a larger extent in the design phase. The interviewees were chosen to represent the normative view of workers at a construction site. The interviewees are however not representative for all performed activities during the production phase, hence the

Peab’s supervisor was chosen to both represent workers from these activities and the project management.

1.6 Disposition

The report begins with an introduction followed by a theoretical framework. The theoretical framework begins with a description of BIM and is then divided in four different parts. The two first parts describe advantages and difficulties when integrating BIM in the construction phase. The continuing two parts are presented to provide an understanding of the different dimensions, elements and Level of Detail of BIM.

Thereafter a chapter, methodology, describes the work process applied in this report to achieve the goal of this report and to reach answers to the research questions.

After the methodology a description of the case and the company Peab follows, tighter with a presentation of how the company work and applies BIM.

The results from the interviews and also an analysis are presented in the result and analysis chapter. The chapter begins with two summaries, presenting the main findings. This is followed by a detailed description of each interviewee’s thoughts and comments.

In the discussion chapter the result and analysis is discussed and compared with the theory. The report is completed with a conclusion, containing suggestion for further studies and recommendations for Peab.

2 Theoretical Framework

Building Information Modeling (BIM) has, during the last years, had a revolutionary development in the architecture, engineering and construction (AEC) industry (Azhar, et al., 2012). This has reshaped and transformed the AEC-industry and the way buildings are designed and constructed. BIM promotes collaboration between architects, engineers and contractors and have changed the way they work (Weygant, 2011).

2.1 Building Information Modeling, BIM

In the construction industry, companies and organisations are facing larger competition as well as economic uncertainty (Deutsch, 2011). Optimising the work processes by efficient use of labour and recourses and reduce waste is, together with shorter schedules and reduced uncertainty, some of the many reasons for the large interest for BIM. The concept was introduced theoretical in the 1970s but its attractiveness started first when the large computer-aided design (CAD) suppliers, such as Autodesk and Graphisoft, began to use the concept (Jongeling, 2008). Even though BIM today has become very popular, there is not only one definition of BIM and in journal articles the definition of BIM often differ (Barlish & Sullivan, 2012). One approach is to associate BIM with the process of creating and using digital models. Another approach is to define BIM as an intelligent 3D virtual building model. Estman *et al*. (2008) make a clear difference between these approaches and describes BIM as a human activity rather than an object. The activity includes processes, tools and technologies, which is facilitated by digital information. The digital documents provide information concerning design, construction and operation of buildings. The 3D virtual building model is termed building information *model* and building information *modeling* is used to represent the activity.

Two, often used, definitions of BIM are presented in the text below and clearly shows that BIM is both a process and software (Azhar, et al., 2012). The National Building Information Modeling Standards (NBIMS) committee of USA defines BIM as follows:

"A building Information Model (BIM) is a digital representation of physical and functional characteristics of a facility. As such it serves as a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle from inception onward. A basic premise of BIM is collaboration by different stakeholders at different phases of the life cycle of a facility to insert, extract, update or modify information in the BIM process to support and reflect the roles of that stakeholder. The BIM is a shared digital representation founded on open standards for interoperability" (NBIMS, 2010).

The Associated General Contractors of America (AGC) perceived BIM as:

"Building Information Modeling is the development and use of a computer software model to simulate the construction and operation of a facility. The resulting model, a Building Information Model, is a data-rich, object-oriented, intelligent and parametric digital representation of the facility, from which views and data appropriate to various users' needs can be extracted and analysed to generate information that can be used to make decisions and improve the process of delivering the facility" (AGC, 2005).

BIM enables new ways of creating, using and sharing building information from the beginning of a building project throughout the buildings lifecycle (Eastman, et al., 2008). BIM is the management of information, and the interaction between technical and social recourses, so the right information can be generated and used at the right time (Jernigan, 2008). The concept is a generic term for how this information is first created, then sorted and used in a quality insured and systematic way (Jongeling, 2008).

The opinion of how far the standards, processes and tools must be developed before BIM can be successful differ (Jernigan, 2008). The vision of BIM is, according to Jernigan (2008) to involve the whole building industry and even though the process today not involves everyone, BIM is increasing the efficiency in the industry.

2.2 BIM's different dimensions

The AEC-industry has traditionally worked with 2D drawings (Linderoth, 2013). When using 2D drawings there is a risk with misinterpretation since the 2D drawings enables the consumer to visualise the solution and, because of for example incomplete information, create an incorrect picture of the solution. By using a 3D-model it is possible to visualise parts of the building and create pictures of how the final solution will look like. The 3D-model becomes a tool for mutual understanding and also a tool for visualising how different changes will affect the different disciplines.

The 3D model has, in comparison to 2D drawings, improved the ability to communicate ideas between actors in the AEC-industry (Jernigan, 2008) and can be used to support e.g. coordination and scheduling (Eastman, et al., 2008). Even if the 3D models improve the ability to communicate and enables conflict resolution before fabrication (Eastman, et al., 2008), there is still a need to interpret information and how elements relate and connect to each other (Jernigan, 2008).

Two other dimensions that can be added to the BIM model are 4D and 5D (Eastman, et al., 2008). In 4D models schedules is included in the model, which allows better and more reliable schedules. In the context of space and time, communication and collaboration is improved and it leads e.g. to disclosures of potential bottlenecks, which contributes to a more efficient schedule. In 5D, cost-related data is connected to the 3D model. When cost estimation is attached to the 3D model, it enables the possibility to generate plans for ordering material.

2.3 Elements and Level of detail

A BIM project can be described as a prototype or a digital presentation of a building object (Weygant, 2011). The ability to make different types of analysis, such as analysis of performance and aesthetics of an unbuilt building, is mostly depending on the level of detail and the precision of contents. The elements or contents, also called components, represent for example walls, floors and ceilings. These elements have the ability to carry information about their specific configurations and arrangements.

Level of Detail (LOD) declares how detailed different elements in the model are (BIMForum, 2013). Level of Development is on the other hand, the grade to which the elements' geometry and attached information has been changed throughout the process. According to BIM Forum (2013) Level of Detail can be seen as input to the element, while Level of Development is reliable output. The American Institute of Architects (AIA) developed, in 2008, the first set of LOD definitions in *AIA Document E202™-2008 Building Information Modeling* (BIMForum, 2013).

A specification of LOD enables practitioners, at various stages in the design and construction process and with a high level of clarity, specifying the content and reliability of BIM (BIMForum, 2013). By standardising the use of the specification, it will become more useful as a communication tool with objectives such as:

- To facilitate and clarify the demand specification of BIM deliverables, both for the contractors and for the client.

- To assist the mangers, during the design phase, to clarify what information and details that needs to be provided at the different stages of the design phase.

- To provide a standard for contracts and BIM execution plans.

To be able to define the progression, the level of detail for each element needs to be defined (Bedrick, 2008). The levels are named from 100 to 500, where the lowest represent a conceptual level and the highest represent precision. The LOD can then be used to define phase outcomes and to assign modeling tasks. The phase outcomes will depend on the element where LOD 100 is the lowest level and the element can obtain other properties, for example cost and assembling, which could be attached to the element and it reaches a higher LOD. What type of critical items that needs to be communicated will affect the LOD (Eastman, et al., 2008). One task may require a more detailed model than another and at different stages in the building process, different elements of the model will progress from one LOD to another higher LOD (Bedrick, 2008). During the design phase elements need to be at one LOD and when the process exceeds to the construction phase many of the elements will have to be upgraded to a higher LOD, see Table 1. The main purpose for standardised LOD is to ensure improvement of communication (Ekholm, et al., 2013). This is made in order to enable the unequivocal exchange of information between two parties and for the content and scope of missions for different actors in the AEC industry. The content of the levels 100 to 500 are explained in Table 1.

Level of Detail, LOD	Explanation
100	Is conceptual with information concerning area, height, volume, orientation and location (Ekholm, et al., 2013; Weygant, 2011). Since the level of detail is very low and only masses are taken into account, the level uses for e.g. project preplanning basic cost estimating (Weygant, 2011). **Element, Interior wall:** "Not modelled. Cost and other information can be included as an amount per s.f. of floor area." (Bedrick, 2008)
200	Consists of approximate geometry, location and orientations (Ekholm, et al., 2013; Weygant, 2011). The walls, floors, ceilings and roofs are added but without any information concerning materials or components. **Element, Interior wall:** "A generic interior wall, modelled with an assumed nominal thickness. Properties such as cost, STC rating, or U-value may be included as a range." (Bedrick, 2008)
300	Shows precise geometry and details concerning individual components but not information concerning their installation or maintenance (Ekholm, et al., 2013; Weygant, 2011). At this level specific cost estimates and construction documents may be generated since specific information regarding the performance aspects of the components and dimensional preference or limitations are added (Weygant, 2011). **Element, Interior wall:** "A specific wall type, modelled with the actual thickness of the assembly. Properties such as cost, STC rating, or U-value can be specified." (Bedrick, 2008)
400	Has, in contrast to lower level, a higher amount of information contained within the object (Ekholm, et al., 2013; Weygant, 2011). Design, fabrication and assembling are details, which beyond the requirements of LOD 300 are needed for this level. **Element, Interior wall:** "Fabrication details are modelled where needed." (Bedrick, 2008)
500	Represents a correct digital representation of the performed construction (Ekholm, et al., 2013; Weygant, 2011). The level is also referred to as *as-built*. **Element, Interior wall:** "The actual installed wall is modeled." (Bedrick, 2008)

Table 1: Level Detail of 100-500

2.4 Implementation of BIM

The general rate of BIM adoption in the AEC industry has been slow but the importance of the adoption has become increasingly recognised by the industry, in order to increase quality, productivity and efficiency (Gu & London, 2010; Khosrowshahi & Arayici, 2012).

Implementation of BIM, to achieve the benefits, depends partly on the organisational readiness to change (Khosrowshahi & Arayici, 2012). BIM implies new business and administrative processes which is important for the employees to accept and comprehend. To enable acceptance and understanding for the new processes, training programme is necessary. Due to the changes, in processes and technology within the organisation, the training has to be accompanied with education. The client of a construction project has a large impact of the spread of BIM adoption, because if the client sees the benefits they can push the adoption forward (Eastman, et al., 2011).

To clarify the implementation of BIM, Succar (2009) have identified the maturity phases and divided them into four stages, see Figure 2. The described process starts with the traditional practice named Pre BIM status. Stage 1 consists of *object-based modelling*, Stage 2 of *model-based collaboration* and Stage 3 of *network-based integration*.

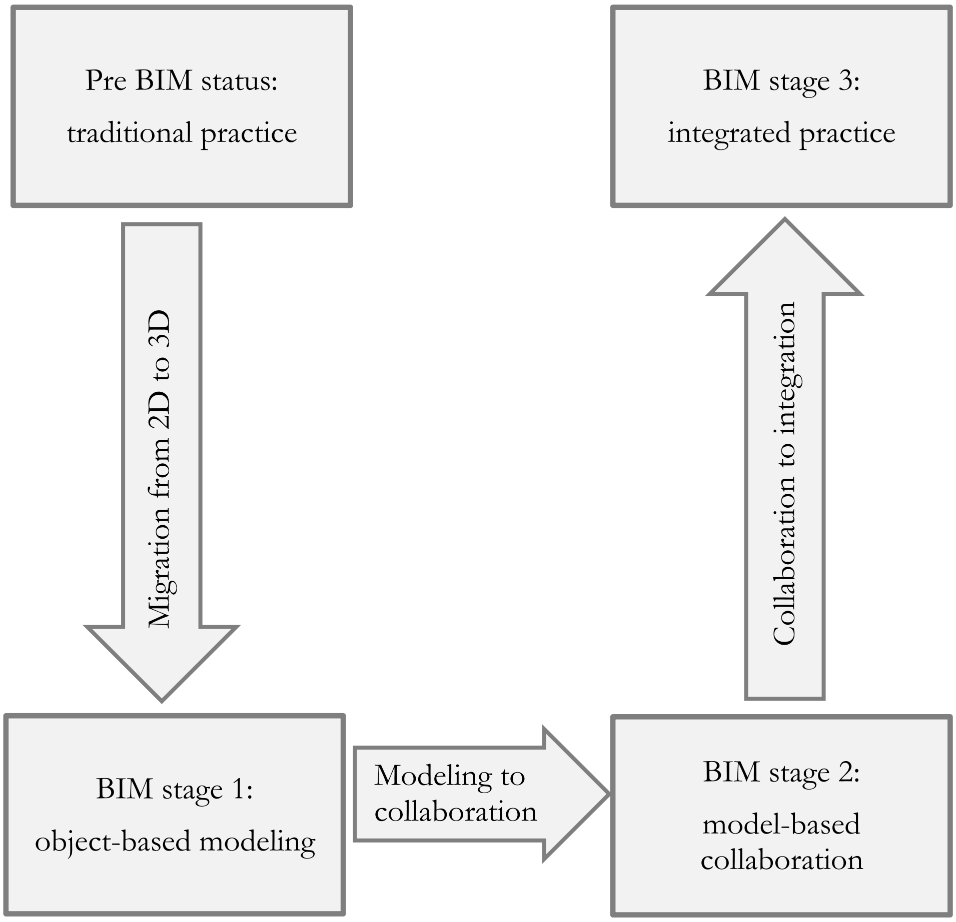
Stage 1 consists of *object-based modelling* and indicates the progress from 2D to 3D (Khosrowshahi & Arayici, 2012; Succar, 2008). The BIM model consists of architectural elements and is still single-disciplinary. Since there are only minimal changes in the process, the work process and organisational behaviour remains.

Stage 2 consists of *model-based collaboration* and implies the progresses from modelling to collaboration and interaction (Khosrowshahi & Arayici, 2012; Succar, 2008). Integrated data communication and data sharing between all project team members and stakeholders will enable the required communication and collaboration.

Stage 3 consists of *network-based integration* and indicates transition from collaboration to integration (Khosrowshahi & Arayici, 2012; Succar, 2008). The step reflects the real underlying BIM philosophy. At this stage, the model is created, shared and maintained throughout the project's entire lifecycle and allows at early stages complex analyses.

- Document-based workflow
- 2D drafting and detailing
- Heart beat linear workflow
- Asynchronous communication
- Adversarial relationship
- Risk shedding
- Lack of interoperability

- Information share and exchange
- 4th and 5th dimensions (time and cost)
- Generate array of analysis driven deliverable
- Clash detection between disciplines
- Asynchronous communication



- 3D object-oriented model
- Automated and coordinated views
- Streamlines 3D visualisations
- Basic data harvested from the model such as 2D plans, evaluations, sections, quantity of take off, lightweight models for internet
- Asynchronous communication

- Multi-dimensional model (nD)
- Complex analysis at early stages such as sustainability, constructability, lifecycle costing, etc.
- Multi-discipline utilise the same model thought an integrated, interoperable or federated database
- Streamlined lean process
- Synchronise communication
- Multi-server technologies for collaboration

Figure 2: Different steps of implementation of BIM. Developed from Khosrowshahi and Arayici (2012).

2.5 Advantages by implementing BIM

To develop the implementation of BIM in the construction industry it is important to measure the advantages and disadvantages of using BIM in construction projects (Jongeling, 2008). To change from the traditional way of working with 2D CAD into BIM projects, specific gains of using BIM needs to be highlighted. There are many benefits by using a 3D visualisation model in a construction project, but BIM is so much more than just a 3D-model (Azhar, 2011). By using BIM processes are much faster and effective, since BIM facilitates information sharing. BIM also generates a better design because building proposals can be thoroughly analysed.

The client can obtain a large advantage by using BIM, since a BIM model makes it easier to understand the building proposal (Jongeling, 2008). Other advantages by implementing BIM in the design and construction phase are that BIM enhance the communication between the different actors in a construction project. The documents, from the design phase are better suited for its purpose, which also leads to a better construction phase. Entrepreneurs' estimate that costs for variations (ÄTA-arbeten) are 50 per cent less when using BIM compared to a traditional construction project. Additional advantages are higher quality of the production, due to the flexibility of documentation output (Azhar, 2011). Also controlled whole-life costs, environmental data and lifecycle data is mentioned as advantages of using BIM.

In the article "*Users-orientated evaluation of building information model in the Chinese construction industry"* (Xu, et al., 2013) the importance of willingness and interest to use BIM, when it comes to adoption of BIM is highlighted. The more people who find BIM easy to use will increase the likelihood of additional users to adapting BIM. Hence to spread the adoption of BIM means create an environment which engages and transmits the BIM concept.

There are benefits in all phases of a buildings lifecycle, in Table 2 a summary of the different benefits for different actors and phases in a construction project are displayed (Eastman, et al., 2011).

Actors and phases	Benefits by using BIM	BIM use
Facilities management and client	Main benefits are ensuring higher quality and better buildings. Other benefits are better teamwork leading to reduced problems and hence a more effective process.	- Increase building performance - More reliable cost estimates - Coordinate the design to shorten the project schedule - Ability to make decisions when they still can influence - Relevant as-built information will optimise maintenance work
Design phase	By using BIM in the design phase a guaranty of consistency amongst all drawings and documents is achieved. Other technical applications that will facilitate the work is simulations, cost estimates, different analysis, the ability to automatically search for clashes and providing a strong base for interfacing analysis/simulation/cost applications and improving the visualisation.	There are many functions in BIM that can facilitate the following analysis: - Structural integrity - Impact of external loads - Temperature - Ventilation - Lighting - How people will move around - Acoustics - Energy use - Water consumption - Waste disposal.
Construction phase	Advantages by using BIM in the construction phase are better processes, which in turn can save both money and time. Another advantage is that BIM can decrease problems and conflicts, by generating a common platform. One major benefit of using BIM in the construction phase is when the major subcontractors also use the model, when detailing their work, this leads to correct clash detection and in turn fewer problems at the construction site.	To achieve all these benefits the contractors need to be involved early in the project and the contractor and owner needs to involve the subcontractors. It is important to know that there is a learning curve by applying BIM in the construction phase and changes needs to be done when switching from traditional drawings to a building information model.

Table 2: Summary of benefits by using BIM in different phases of a construction project (Eastman, et al., 2011).

2.6 Difficulties by implementing BIM

There are not only advantages by using BIM and therefor BIM cannot be seen as a panacea for all construction projects (Azhar, et al., 2012). Some reasons why BIM is not more used in the construction industry is according to Gu and London (2010):

- A divided construction industry and lack of coordination
- There is very little training and awareness
- Hesitation towards changing traditional work processes in the construction industry and unwillingness to learn new things

Some reasons, according to Azhar et al. (2012), affecting the use of BIM implementation is:

- Not enough competence amongst the employees
- It is a high cost to apply BIM in a construction project
- There is an unwillingness amongst architects, engineers and contractors
- The work processes are not cooperative and there is lack of modeling standards
- The programs are not interoperable and there are legal issues regarding contractual arrangements

Another obstacle to overcome for a wider adoption in construction projects is the clarity of roles (Gu & London, 2010). It is very important to clarify the different roles and responsibilities, since there are often many different actors involved in projects in the construction industry, to facilitate BIM implementation. Some risks when implementing BIM can be categorised in two groups; risks related to the Technology and risks related to the Process. In the category, risks related to Technology lack of BIM standards is one part (Azhar, et al., 2012). This means that since many actors and firms add their information in one model, problems can arise if each actor and firm has their own standards. If there is no consistency in information context and formatting, this can lead to inconsistency in the model and if this is not detected it will be an inaccurate BIM model. Interoperability is also a technology risk. Even though interoperability issues have decreased as a result of the adoption of Industry Foundation Classes (IFC) and XML Schemas, there are still some issues regarding different actors using different software.

In the category, risks related to process, legal, contractual and organisational risks are included. One risk concerns the ownership of the BIM data, since all actors work in the same model (Azhar, et al., 2012). One way to eliminate this risk is to address the problem already in the contract documents and highlight who has the ownership rights and responsibilities. Another problem is who has the responsibility of all the changes and updating different actors are making along the road. To deal with this risk someone needs to review all the BIM data, which leads to a new cost in a construction project, which someone of the actors must pay for.

Another barrier to a broader use of BIM is that since few in the construction industry has experience of BIM, there is no explicit knowledge of what the industry need and require of BIM (Gu & London, 2010).

3 Methodology

3.1 Research approach

The following methods and techniques have been chosen to achieve the goal of this study and to reach answers to the research questions. This study is a qualitative research, even though some writers find the distinction between qualitative and quantitative ambiguous, there is not much pointing in the directions that the distinction will be diminished (Bryman & Bell, 2011). The qualitative method has been chosen since this method put emphasise on words opposite to the quantitative method which emphasises on numbers. The qualitative method is also inductive, which means theory generating, instead of the quantitative which mostly tests theories. The process of this study is displayed in Figure 3.

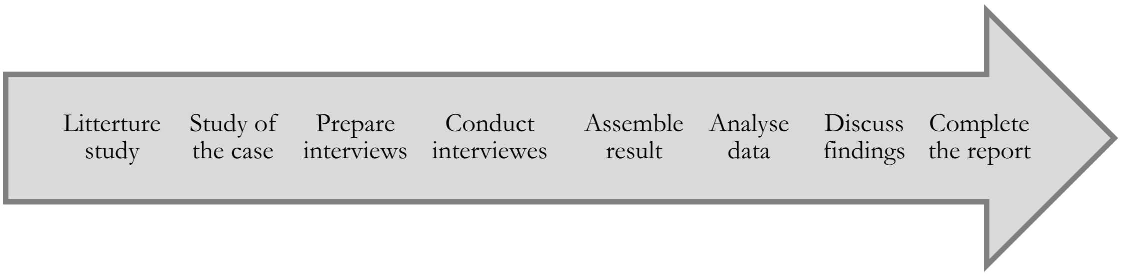


Figure 3: The work procedure of this report

3.2 Literature study

A literature review has been conducted to get background information of the selected area. Reviewing literature is necessary for finding out what is previously known in the selected area, relevant concepts and theories (Bryman & Bell, 2011). It is also important to learn about what research methods have been used and if there are any unanswered research questions. This supports the reports reliability and prevents authors of doing work that has already been done. To be able to perform good interviews and to gain knowledge from these, a good and a deep understanding of the subject is necessary (Kvale & Brinkmann, 2009). The literature review is mainly based on published scientific articles, books and BIM standards. The focus has been on BIM in the production phase, level of detail, implementation of BIM and advantages and obstacles by the implementation.

3.3 Empirical data collection

Empirical data have been collected through documents, models, a case study and interviews. To create a basis for how Peab work and relate to BIM, pre-interviews were conducted with Peab's Chief Technology Officer (CTO), a BIM coordinator, the client and a supervisor at the construction site at Lyckholms.

3.3.1 Documents and models

The documents that have been used in this report are organisational documents from the studied company. These documents, such as Peab's BIM guidelines, BIM-model and schedule, were used to understand the company's previous work with BIM and as a tool when the interview questions were formulated.

3.3.2 Case study

While using a case study one can also apply quantitative or qualitative research (Bryman & Bell, 2011). A case study can be a single location, a single organisation, a single person. But a case study can also include multiple cases (Yin, 2009). The case study chosen in this report is a single location. Since the company studied in this thesis does not practice BIM to the same extent in all their projects, one project where BIM was used in a greater extent was chosen. The case study has been used as a background and complement to the interviews. The case study included visits at the construction site of the project Lyckholms, where processes were studied.

3.3.3 Interviews

By conducting interviews empirical data was collected, to reach the goal of this report. The interviews conducted were qualitative and semi-structured. The reason for choosing semi-structured interviews was to have some structure and a schedule of the questions that were going to be asked, but in the same time this approach gave opportunity to step outside the frame and ask further questions (Bryman & Bell, 2011). A semi-structured interview is also specified by short questions and longer, spontaneous and relevant answers (Kvale & Brinkmann, 2009). By performing a qualitative interview the knowledge is produced socially in the interaction between the interviewer and the interviewee (Kvale & Brinkmann, 2009). Before the interviews were conducted a lot of time was spent on preparing, because, according to Kvale and Brinkmann (2009), the quality of the knowledge that is produced during an interview is depending on the preparation. Problems with qualitative interviews are that is difficult to generalise the result and that the choice of interviewees will affect the findings. For example could the choice of interviewees create bias in the result since it is only the interviewees own thoughts that are expressed during the interview.

Before the interviews took place, a workshop was arranged at the site office, at Lyckholms. The workshop was part of a project, where researchers at Chalmers University of Technology and employees at Peab are conducting a feasibility study on initiative from Svenska Byggbranchens Utvecklingsfond, SBUF. The participants were representatives from Chalmers University of Technology, Peab and different ongoing theses, together with the disciplines' installers and workers operating at Lyckholms. During the workshop the participants were informed about BIM, the ongoing projects and theses. There was also a presentation of the 3D-model of Lyckholms, showed in a head-mounted display, see Figure 4.

The interviews were conducted with all current disciplines working at Lyckholms in the construction phase and at each interview one discipline was represented. The different disciplines belong to other companies than Peab. Only a few disciplines, such as painters and carpenters, were not directly interviewed, but were represented by Peab's supervisor. During two, of the total six, interviews two interviewees participated, which was a request from the interviewees. The interviews were conducted face to face in Swedish at the construction site and the time deposited was about 60 minutes. First the purpose of the interview was explained and permission to record the interview was asked for and also if the interviewee had any questions before we should start. The first questions concerned the interviewee's background, to get the interviewee started and then the questions concerning the subject were asked, see questions in Appendix A. One asked all the questions and the other took notes, if there were any ambiguities both could cut in. To get answers about the 3D-model of Lyckholms, it was found to be most appropriate to display the model at the same time when the questions were asked. The 3D-model was showed in a head-mounted display, this is a device in form of a helmet with screens in front of the users eyes. The screens showed the building, Lyckholms, in a real size 3D vision, with the possibility for the interviewee to orientate by themselves with a handheld device, see Figure 4. The reason for using the head-mounted display was to deviate from the traditional 2D-drawings and usual work procedure.

Figure 4: The use of the head-mounted disply during the interview, (Viklund Tallgren, 2014).

3.4 Data analysis

The quality of the interview is critical for the quality of the analysis of the interview. There are different ways to analyse interviews (Kvale & Brinkmann, 2009). The method used in this report was that after the interview the result from notes, memory and records was summarised in a text. There are no clear guidelines how to analyse qualitative data (Bryman & Bell, 2011). In this report the following procedure was applied. The first step of the analysis was to code all the written text, which means that all the key points were highlighted, then all the codes with the same meaning were grouped together, these groups are called concepts (Bryman & Bell, 2011). The next step was to group the concepts to generate theory which could be connected to the already existing theory.

4 Case

Peab is a construction and civil engineering company, acting on the Nordic construction market (Peab, 2014). The company's business areas are construction, civil engineering, industry and property development construction. The construction segment builds, in cooperation with subcontractors and suppliers, commercial, public and industrial facilities. Peab have approximately 130 offices located in Sweden, Norway and Finland, 13 000 employees and about SEK 40 billion in net sales, 2013 (Peab AB, 2014; Peab, 2014). The Peab share is listed on NASDAQ OMX Stockholm.

4.1 Peab and BIM

To get information about how Peab is working with BIM, a pre-interview with the CTO was held. The CTO is a former BIM strategist and his main work is to handle overall BIM questions. He is part of a team which main focus is development and different strategy questions. One of the team members works specifically with BIM and that person's main work is the implementation of BIM and to support the production. Another person included in the team works 30 per cent of his time with 5D in BIM and the development of this. In Peab there are also other people in the different regions with specific competence in BIM which main focus is to work with BIM in specific projects. The CTO have realised that people who have specific interest in BIM is needed to enhance the future work with BIM.

The CTO explains BIM as intelligent 3D-models and that the communication in a construction project is moved from several paper drawings into one 3D-model. The BIM concept seems more indefinable to many, than what it actually is. He explains BIM as pieces of Lego that one put together but that the pieces instead are digital building blocks. BIM enables testing of different solutions and actors in a BIM project are therefore more prepared for the project, compared to the traditional way.

The car industry has, according to the CTO, come further in the digital development and is using the digital model for development and communication. The car industry does everything digitally and they test deviations easier to ensure a better end product. The CTO believes that the construction industry should be able to adopt the same way of thinking but the difference is that the car industry, manufacture the same product over and over again. The reply to this is that the construction industry almost does the same thing in all projects with similar buildings and to start from the beginning every time is unnecessary.

Peab usually use a 3D-model in projects which are larger than 100 million and also in projects with new buildings in big cities but a standardisation for when a 3D-model should be produced is requested. It is today more common that clients, in the specifications, pose the question about how Peab works with BIM and there are sometimes demands for 3D coordination. Who sets the demands vary with the client and it is often the large clients that have the demands, since they know it will pay off in the end. There are at the moment not that many facility managers that have had demands about 3D coordination, but the CTO believes they will start to request it. When Peab procure subcontractors for 3D coordination projects, the subcontractors need to be able to deliver a 3D-model, and compared with the clients, Peab have higher technical demands.

According to the CTO one of the greatest benefits, by using BIM, is a greater understanding among the members through the ability to see how calculations have been done and how the creator has thought during the creation of the schedule. This in turn will lead to an increased productivity. In the future more suppliers will deliver their components digitally, and details in the 3D-model will be more specified. The supplier will also be able to get this information so he/she can see the amount of the product and when to deliver the product. Hence the model will be more alike the reality and additionally one step towards greater efficiency is taken. The step from using papers, to working in the 3D-models will go quicker.

4.2 Peab's BIM vision

Peab's BIM vision is to integrate all processes and BIM will function as a binder which connects all processes and activities. There should be one 3D-model which is the original. This 3D-model is used for adding and collecting inputs and outputs. This is Peab's technical vision a central information flow. An overall vision is to increase the productivity and the quality of Peab's work.

Peab's strategy is, according to the CTO, not to focus on BIM specialists, instead they want to develop their existing roles, their business, how they work and to integrate BIM into all this. As mentioned earlier Peab have clearly stated that their overall goal is not to "work with BIM", but instead use BIM as a tool to increase efficiency in a construction project.

Peab have developed standards, processes and tools to enable the use BIM within the design phase. The guideline consists of directions and delivery requirements for the design and the level of detail, in the 3D-model, are currently based on three levels, see Table 5.

Level	Explanation
1	A model in a very early stage, to enable further investigations. The concept model includes surfaces, volumes and shapes.
2	An object divided model where for example beams, doors, windows are included but the materials are not yet specified. This level enables indicative estimations and schedules. This corresponds to architectural and system plans.
3	A model matching the detailed construction documents. This level represents precise definition of the dimensions and materials. This corresponds to construction documents.

Table 5: Peab's different levels of detail in the 3D-model.

Peab works with BIM at three different stages. Stage one is 3D coordination and the 3D-model are used to prepare the actors for the work and to ensure that all solutions have been considered. Stage one should, in numbers, result in zero faults in the design phase. The vision of the second stage is to have zero faults in net quantities. Because quantities are both input for planning and calculations, this could help Peab to ensure that they do not accept non profitable jobs, due to for example miscalculations. The third stage is 5D BIM, where they integrate calculation, timetable and the 3D-model.

By using 5D BIM, the CTO believes that they would be able to increase their productivity by ten per cent. He compares stage two with 3,5D, since they use the model for quantities. The spread of how much BIM is integrated in the work process differs geographical and at the moment there is around 15-20 ongoing BIM projects in Sweden. The reason for this low number is because Peab is still developing the work process. Peab have a few pilot projects where 5D is tested, to be able to later deliver a complete 5D solution.

4.3 Lyckholms

The block Lyckholms is located in central parts of Göteborg, close to Liseberg (Peab, 2013). Lyckholms production of beer started in 1881 and it was at the same time the first building was built. The production ended in 1975 and Peab is today building two new buildings with total 20,000 square meters. The first occupation occurs in 2015 and Peab will, together with other companies, use the buildings for offices but there will also be cafés and restaurants.

Different divisions in Peab represent the projects client and the contractor. The project is carried out in a design and build contract. Peab is responsible for the supervising of the project and other actors are procured from other companies. All disciplines, except supervisor, are therefore consisting of subcontractors. Peab as a client had no demand for using BIM during the project, according to the client this was since they are not familiar with BIM and the benefits of it. Peab as contactor had the vision of using 5D, but without generating any extra costs. To realise the vision of 5D, Lyckholms became an internal lobbying project. Peab wanted to get people interested in BIM, because without any interest, little understanding of BIM would occur. Sometimes a solution must be presented, instead of asking what people want. The reason for this according to the CTO is that not everyone is an innovator and to think outside the box is difficult.

Peab's first vision of BIM in the Lyckholms project was that it was going to be the highest level of BIM, 5D, to allow them to test their competence concerning BIM, but the level of ambition was lowered. Before they have used consultants for this type of work, but in Lyckholms Peab embraces the role and takes the lead concerning BIM. One reason for not keeping the first vision, of 5D, was that the project had progressed and the cost estimating was already done. The CTO believes that Peab should have clarified the BIM focus earlier which would have made it easier for integrating BIM in the project. They had a few workshops on Lyckholms to see if they could use BIM for tenant improvements and for net quantities.

5 Result and Analysis

5.1 A summary from the interviews

All of the interviewees have worked several years in the construction industry. The information all disciplines use is drawings and descriptions. The majority of the disciplines use information from other than their own discipline and also the 3D-model, only two disciplines exclusively uses their own drawings and descriptions. It is only one discipline that does not use all the assigned information and only two that could use additional information. Two interviewees wanted their information earlier, than when they usually get their information. Three of the total eight interviewees had heard about BIM, before the workshop, but only two had used BIM in earlier projects. Only one interviewee knew from the start that Lyckholms is a BIM-project. All the interviewees, except one, had been informed about the existing 3D-model of Lyckholms. The majority have used the 3D-model for visualisation and problem-solving. A summary are displayed in Table 6.

STATEMENT	Prefabrication	Ventilation/ 2 participants	Plumbing	Sprinkler/ 2 participants	Electrician	Supervisor
1. Long experience from the construction industry	•	•	•	•	•	•
2. Use the following information:						
-Drawings and descriptions	•	•	•	•	•	•
-Other disciplines information		•	•	•		•
-3D-modell		•	•	•		•
3. Use all assigned information	•	•	•	•	•	
4. Need additional information	•			•		
5. Need information earlier in the process	•				•	
6. Have knowledge/heard of BIM				•/-	•	•
7. Have used BIM in other projects				•/-		•
8. Know that Lyckholms is a BIM project						•
9. Aware of the 3D-modell of Lyckholms		•	•	•	•	•
10. Have used the 3D-modell:						
-For visualization		•	•	•		•
-For problem-solving		•	•	•		•
11. Positive attitude towards new technology	•	•	•	•	•	•
12. See BIM as a substitute						
13. See BIM as a complement	•	•	•	•	•	•

Table 6: Summary from the interviews.

Explanations of the different statements in Table 6:

1. To be considered to have long experience from the construction industry includes several years of working experience in their specific discipline.

2. The interviewees have access and use different kind of information, which is divided into three categories to illustrate the use of different information.
3. The interviewees are given an amount of information from their company, the table shows how many of them who uses all assigned information.
4. This statement indicates if the interviewees are in need of additional information than assigned.
5. Many of the interviewees stated that they get their information when they arrive at the construction site, the table shows how many of them that need the information earlier.
6. The table shows if BIM was a new concept for interviewees.
7. The table shows which of the interviewees that had worked with BIM in earlier projects.
8. The statement indicates how many of the interviewees that knew Lyckholms is a BIM project.
9. The interviewees have access to the 3D-model, via the intranet, the table show how many interviewees were aware of this.
10. The 3D-model can serve many purposes, the table displays the most common.
11. The statement shows the general perception of each interviewee's opinion towards new technology.
12. BIM can be seen as a substitute for the drawings and its related documents which the interviewees use today, the table shows how many of them would consider this as possible.
13. BIM can also be seen as a complement to the drawings and its related documents which the interviewees use today, the table shows how many of them would consider this as possible.

A summary of the findings, discovered without any guidance or questions, from the interviews are presented in Table 7. The reasons for highlighting the ideas and solutions was to investigate to what extent the different disciplines could use the information in a BIM model and to discover barriers that must be conquered to enable a further development of BIM guidelines.

STATEMENT	Prefabrication	Ventilation/ 2 participants	Plumbing	Sprinkler/ 2 participants	Electrician	Supervisor
1. Would like an overview	•		•	•		•
2. Want possibility to print a 3D-modell view		•	•	•		•
3. Want the different disciplines work to be colour-coded		•	•	•		•
4. Want to be able to switch on/off other disciplines work		•	•	•		•
5. LOD	350	350	350	350	500	350
6. Want information about location	•					•

Table 7: Summary from the interviews.

Explanations of the different statements in Table 7:

1. There was a request from the interviewees to be able to get a bird's-eye-view of the building, and not real sized view all the time.
2. Since all of the disciplines have their information with them on site, there was a request of the possibility to print views directly from the model. So they could bring it with them, because it would not be possible to only remember the view.
3. There was a demand for colour-coded components, to make the model more suitable for the interviewees needs and to separate the different disciplines components.
4. Also to simplify the usability of the model, the interviewees want to be able to switch on and off the displayed components.
5. The table shows the different opinions of how detailed the different disciplines components need to be, in the model, in terms of LOD.
6. To make it easier to orientate in the model there is a demand of information where in the model the user is located, in that specific moment.

5.2 Result from each interview presented separately

5.2.1 Interview A – Prefabrication

The interviewee has been in the construction business through almost all his working years. He has experience from both Sweden and Denmark. He has been working for the company the last 13 years and his work is montage of prefabricated elements.

The information the interviewee uses to execute his work, is drawings and its related documents. The interviewee almost never uses information from other disciplines, since they most often start their work after the interviewees work is finished. Sometimes other disciplines execute their work at the same time as the interviewees, but in those cases the interviewee still does not use their information. He says that their information should look the same as his. The interviewee gets his information from five minutes up to some hours before he starts his work. He says that they are supposed to have a review on site before they start but it is hard to have time for this, because when the trucks arrive with the material they need to start mount the elements, because it is expensive to keep the trucks waiting. He adds that it would be good to get the information a little bit earlier, because every time they get to a new place it always takes some time to acclimate. The information the interviewee does not have today is an overview drawing and he says that these are difficult to get. They usually make their own drawing to easier have a view of the entire project.

The interviewee did not have the opportunity to participate during the workshop and had no knowledge or experience from BIM.

The interviewee thinks it is good with a 3D-model of the building, which displays the entirety. An advantage the interviewee mention about the model is that it is good to see the building more finished. Because when the interviewees work are finished it is only a shell he deliver. The interviewee cannot see any advantages by using the model in the work he performs at Lyckholms, since it is a rather easy facade, they mount. But he mention that a model could be useful for him when constructing buildings with more pillars and bay windows, since these facades are much harder to figure out how they are supposed to look like from the drawings.

Information the interviewee would like to be displayed in the model is measurements and embedded components for the welders. He thinks it would be easier to orientate in the model if the different floors were displayed. Important information, he would like to have displayed, is whether or not there is a ceiling. If this was displayed it could save them a lot of time, since if the building is supposed to have ceiling, the millimeter accuracy is not equally important. It is not always that they get this information but in this project they did. Additional information the interviewee would like to be displayed in the 3D-model is connections and how they relate to other elements.

One disadvantage the interviewee mentions about the model is the possibility to bring it with them. They always have their drawings with them. They seldom ask Peab’s supervisor, because if they have thoughts about anything, they need to call their constructor. Every change they make could have impact on the strength of the building and reimbursements could be needed.

5.2.2 Interview B – Ventilation

During this interview there were two participants, which have worked several years in the construction industry and have worked at the company for 15 years. They work together and are at Lyckholms the two installers which together perform all ventilation installations.

The interviewees have a foreman which provides them with information and documents regarding the work. The documents consist of drawings and its related documents. They use all information in these documents but do not request any additional information. They approximately use the drawings once an hour and often more, which implies the drawings to be close at hand. The different disciplines’ drawings are available at the site office and there is, according to the interviewees, a good communication between the different disciplines. The interviewees comment that the communication is important to be able to solve problems such as clashes.

BIM was something completely new for the both interviewees. They have not received any information about the use of BIM during the design of Lyckholms, but they have noticed that the designer must have worked a little extra with the drawings during the design phase since there are fewer clashes than usual. The interviewees think it is strange with clashes in this project, since it is a new designed building.

"There are unnecessarily many clashes! It should actually be none, since it is a new built building, but still there are clashes.”

Some areas in the building are really difficult to accomplish since it is designed in a special way. The interviewees got by chance the information about the existing 3D-model and could, with help from Peab’s supervisor, use the model and get some answers on some questions concerning the design.

A coordinated drawing and section drawings are, according to the interviewees, something very helpful but are often something they need to ask for to get.

"Often when you ask for section drawing, they say that it is too expensive to produce“

Therefor it would be desirable to be able to print views directly from the 3D-model. Information that is needed in the model is dimensions and elevations but also by your own be able to measure and see distances between different disciplines' installations. To create a picture and visualise how it will look like is something really positive, according to the interviewees, and colour-coding for different disciplines' installations would be optimal. Hence it would be even better if there were a distinction between the different discipline's components.

When the interviewees have problems and questions, they ask Peab's supervisor for supervision. It would be good if they, together with Peab's supervisor and other disciplines, could see the 3D-model and based on the model discuss the problems.

5.2.3 Interview C – Plumbing

The interviewee has been employed at the subcontractor company since 2001 and has during all these years worked with the same type of plumbing installations. At the construction site, there are two plumbers from the company, which together perform the work at Lyckholms.

The two workers have a foreman which represents the company and are present at the construction site a few times a week. The foreman has contact with Peab's supervisor but the two workers also have direct contact with Peab's supervisor for example during the morning meetings. The morning meeting takes place, at the construction site, every morning on Peab's supervisor's initiative. There is a review of the ongoing activities and a discussion of eventual questions and problems with all workers at the site. The interviewee comments that a lot of the communication, between the workers at the site, takes place during the lunch- and coffee breaks.

The foreman is the one that first gets the information regarding the upcoming work. The documents, which are provided and there after used by the workers, are drawings and its related documents. According to the interviewee the plumbing installations are similar for most of the building projects. The interviewee therefore believes that an earlier delivery of the documents to the workers is not needed and accepts today's situation where the documents and the workers often enter the site at the same time. All information existing in the documents are, according to the interviewee, useful and do not require any additional information.

The interviewee had, before the start meeting, never heard about BIM. He had not received any information concerning the vision of using BIM, in a larger extent, at Lyckholms. Peab's supervisor has introduced the existing 3D-model to the workers and they have, a few times, used it as a tool to solve problems such as clashes.

"I have on previous projects never been able to use a computer and by myself see the 3D-model, but we have sometimes got printed 3D-views."

To have the opportunity to decide what part of the building in the 3D-model which is shown is according to the interviewee, one of the advantages with the existing 3D-model. Another advantage is that one can get a comprehension of the whole picture.

At the time the 3D-model is displayed for the interviewee, he directly starts to use it and studies how the area, which he works with at the moment, will look like when all installations are completed.

"It's smart to see what the designer had in mind, since this particular view is very strange on the drawing. But you will probably have to have both parts anyway. "

To be able to use the 3D-model in a larger extent, the interviewee needs more information within the model. The information regarding dimensions, materials, height and distance but the interviewee also stresses that most of this information already exist in the drawings.

5.2.4 Interview D – Sprinkler

During this interview two workers participated. They both work as installers of sprinklers at the company. One of the installers has ten years of experience of the construction industry and has had the same type of work these years. The other installer has been in the plumbing business for 30 years and some of these years he worked in Norway.

The information the interviewees mainly uses when they execute their work is drawings and its related documents. One of the interviewees usually participates in the start meeting, these meetings takes place a few months before the construction phase begins. During these meetings he gets introduced to the project. Most times, the interviewees get their information they need to execute their work the same day when they arrive to the construction site. They say that their foreman, at their company, get the information earlier. The interviewees use information from other disciplines, mainly plumbing and ventilation and this information is displayed in a coordinated drawing. This drawing is only given to them if they request it, which they not always do. Usually they ask for it if some problems occur. In this project they have not needed this drawing since their work progressed as predicted.

The interviewees find the information they are given sufficient, but it happens that they get too little information. In these cases the main problem is that the right drawings do not arrive in the right time.

Before the workshop, the interviewees had not heard about BIM. The interviewee, with experience from Norway had worked in projects where they used 3D-models.

The interviewees did not know that Lyckholms was a BIM-project. They heard about the 3D-model that they could use during the morning meetings. In the beginning of their work they had some problems in a shaft so they appreciated that they could use the 3D-model and it helped them solve some problems.

One of the interviewees participates in all morning meetings. The same interviewee has also used the 3D-model of the project, with help from Peab's supervisor. The main reason for the use of the model has been when collisions have occurred. Both of the interviewees think it is good that there is a 3D-model of the project, so that they can use the model and see how their work will look like when it is finished. For example if there are insecurity about different heights, the model is very helpful. Most collisions they solve amongst them self to save time, if they were to ask their foreman, it could take days before their work could continue, due to investigations. They like this way of solving collisions.

One of the interviewees still wants to keep their drawings, since he wants to be able to bring them with him. He stresses that they can bring the drawings, but if they had to go to the site office to get the information needed it would take too much time. Also they would not be able to keep the information in their head only, when they went back to their working station. Information they want displayed in the 3D-model is heights and dimensions. Another function they want is some type of calculator, they can use for adding and subtracting distances. When they look in the model they say that many of the things they see, they also see in their drawings they use. Some of the advantages with the model is that they get an overview of the project and that they can see how things will look like when it is finished.

Another comment about the model is a request to see which work belongs to which discipline, but again they mention that they can do this in their drawings. They would also like to switch on and off work that belongs to the other disciplines.

The interviewees say that anything that can facilitate their work is good.

5.2.5 Interview E – Electrician

The interviewee has been within his work discipline for nine years. They are two from the company that works on Lyckholms at this stage of the project, but further ahead they will be up to 15 to 20 people. The interviewee has only been working in large construction projects.

The information the interviewee uses today is several drawings and its related documents. His discipline has, compared to others many drawings, approximately seven for each floor. The interviewee brings all of these drawings with him on site. When he gets his information differs a lot, in this project he got the information a few weeks before his work started. It matters when he gets the information, if he gets it in time there is time for preparation and they can also order material. The interviewee seldom uses information from other disciplines, since his installations do not need millimetre accuracy. There are exceptions, for example sometimes the interviewee uses information from kitchen suppliers. This is so they will install their work in the right place in relation to the kitchen appliances. If there are collisions, the interviewee says that it is always his discipline that needs to move his work. The interviewee feels he has sufficient information to execute his work.

The interviewee had heard about BIM earlier and thinks it is a good idea to use in a feasibility study of a project, but he cannot see the use for his discipline of BIM in the production phase. Although he can understand if some of the other disciplines could find BIM useful in the production phase since they have tighter shafts. The interviewee did not know that Lyckholms was a BIM project. Peab's supervisor told them that there was a 3D-model of the project and that could use it if they wanted. The interviewee has not used the model and he does not think he will use it later on in the project either. This comment he bases on an earlier project he participated in, where the supervisor used a 3D-model even more than in this project and in that project he had no use of the model.

The interviewee does not like that he has to move all around when looking on the model in the head-mounted display. He could have watched the 3D-model on a computer screen, it would not make a difference. He says that the information in the model is the same as on his drawings. He thinks one advantage could be that all drawings are visualised together, for example all installations on one wall is displayed, which means that he does not have to scroll through all the drawings. But he adds that this could also be solved with a paper drawing, but they do not ask for it today since it is an extra cost.

The interviewee does not think that there is any information that could be added in the model that would help him. He gives an example that he can see the fittings and where they are placed, but he cannot see how they are installed. Some of their installations they need to adapt to reality, for example where the grid is they can place suspended luminaires.

The interviewee does not think the model would help his discipline when collision occur, because he says that his discipline always needs to move their work since they perform their work the last of all disciplines. Despite this he can understand that other disciplines could have more use of the model.

5.2.6 Interview F – Supervisor

Two of Peab's four business areas, construction and civil engineering, are represented at the construction site. The interviewee works together with three others within the management and has worked in different positions within Peab since 2006.

To facilitate the work at the site, for example logistics, the management are each day arranging the short morning meetings together with the workers at the site. During the meeting a review of conducted and future works is done and also coordination of external logistics. The interviewee has daily contact with the different workers and they get in touch with him when problems and issues arise. The interviewee uses drawings and the existing 3D-model. He has not been part of the design but since he was responsible for the demolition project, which was located at the same area as the current project, he was in an early stage able to access information regarding construction, which he believes is very beneficial.

The interviewee has extensive knowledge regarding BIM and is well orientated in the existing 3D-model. As a supervisor, the interviewee has access to all the different disciplines' drawings and to the 3D-model. A coordinated drawing, was often used traditionally, but since the 3D-model provides more information than just indicates clashes, the 3D-model replace that kind of drawings. The interviewee assumes that the 3D-model will be a helpful tool at a later stage in the process, when more difficult and complicated installations will be executed, though he is unsure if all disciplines will obtain assistance from it.

In order to plan, in which order the installations will take place, the interviewee finds the 3D-model useful since it enables visualisations of the area before the work has started. The BIM coordinator has helped creating shortcuts in the 3D-model, so the tool has become user-friendly and for example made it easy to move between the different floors in the model.

The existing 3D-model is today, according to the interviewee, basically used for visualisation. If the 3D-model had not existed, more section drawings would be required and some areas with complicated installation would have been difficult to solve. Despite this, there are no directions from Peab that the 3D-model should replace the section drawings.

A bird's-eye-view and to easy mark where to start, within the model, is something the interviewee request. To mark material within a specific area and receive a material specification of this marked area, to be able to make an order, is a future preference. The interviewee also proposed that the different materials holds information regarding article numbers since Peab often order from the same supplier. The interviewee does not see any obstacles concerning the technical use among the workers at site but he states the importance of updated information.

"It's really important to ensure that what the workers look at really is right at the moment"

If, and when, BIM becomes 5D the interviewee believes it will require someone to be responsible for questions concerning the use of BIM and the distribution of new updated information to the end users. Someone has to physically upload the latest model and it is important that someone is responsible for that task. Today the changes are informed by e-mails but the interviewee is not quite sure who is responsible for this.

5.3 Advantages and Obstacles

In Table 8 potential advantages and obstacles, which were detected during the interviews, when using BIM in the construction phase, are listed. One advantage that often occurred amongst the interviewees was that BIM and the 3D-model generated a chance to visualise the drawings and create a mutual understanding for the yet not built. Another advantage is the overview of the area, or the space, where all different disciplines' work are gathered. Since the 3D-model could be viewed from different angles, it provides an opportunity to choose sections, which is not possible to see with single 2D drawings, and expensive sections has to be requested. All these advantages offer together opportunities, for supervisors, installers and workers at the construction site, to together solve problems such as clashes that are not solved during the design phase.

Advantages	Obstacles
Visualisation	Learn a work process
Problem-solving	New technology
Overview (including all parts)	New profession role
Choose sections	Need to go to the site office
	Communication flow

Table 8: Advantages and obstacles when integrating BIM

When using BIM in the construction phase, some potential obstacles were detected during the interviews. Since the different disciplines perform their work at different locations at the site, a potential obstacle would be the time consuming activity for moving from the specific work location at the site, to the location of the 3D-model, which might be the site office. To learn the new work process is, together with learning new technology, another potential time-consuming activity. The last obstacle which was mentioned during the interviews was that later on there might be need for a new profession role. This professional role would be responsible for BIM, the 3D-model and the communication and information flow between all parties, but could lead to an extra cost for the project.

During the interviews the following communication flow between the Management team and supervisor, the subcontractors' foreman and the worker was revealed, see Figure 5. The figure displays the communication channels between management team and supervisor and worker and also management team and supervisor and foreman. Besides these communications a communication channel between the foreman and worker occur. According to the interviewees the information concerning BIM has only been communicated from the management team and supervisor to the workers and no communication flow regarding BIM between the foreman and workers have existed.

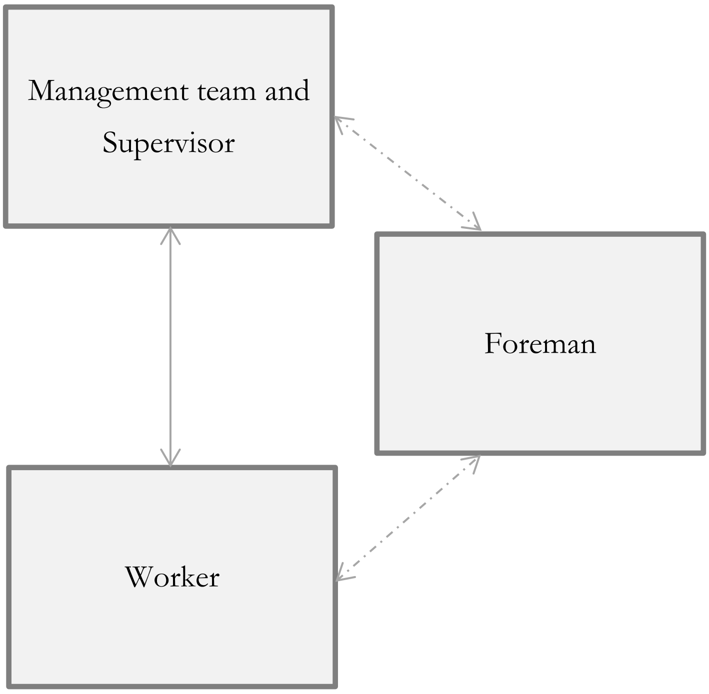


Figure 5: Communication flow amongst actors in the construction phase.

6 Discussion

6.1 BIM as a concept

The question "What is the general knowledge, concerning BIM, among workers in the production phase?” was asked within this study to provide a basic understanding of the workers thoughts regarding BIM, in a BIM-project. Opinions regarding BIM and their perception of a new way of working and use information, during the construction phase were investigated to also contribute to this basic understanding.

The result shows that many of the workers at the construction site have little, if any, knowledge regarding BIM even though the concept, according to Azhar et al. (2012), have had a revolutionary development in AEC-industry. The opinion of how far BIM must be developed before it can be seen as successful differs (Jernigan, 2008). Therefor it is difficult to answer if the level of knowledge among the workers will affect the outcome of use of BIM. Peab have developed standards, processes and tools to enable the use of BIM within the design phase and the result from the interviews shows that the supervisor and the management team are aware of the useful information and benefits of BIM, in the design phase, and also when transferring information into construction phase. Some of these benefits, which became explicit during the interviews, were also declared in the report’s theoretical framework. The chance to visualise parts of the building before it is built is one of these benefits. The visualisation increases, among the management team, the understanding of how the final solution will be and how different changes can obstruct the work for the different disciplines (Linderoth, 2013). The visualisation also becomes a tool for the management team to check if everyone has understood how different solutions are meant to be implemented and creates a mutual understanding among the workers.

One long term goal is definitely to involve everyone, in the construction industry, in BIM but BIM is possible even though not everyone is part of the process (Jernigan, 2008). The interviews indicate however that there is an information gap in the work process, which leads to a risk for not assimilate the benefits within BIM and in this case also a low utilisation of the 3D-model. Peab have, as mentioned earlier, developed standards, processes and tools to enable the use of BIM within the design phase. However the interviews show that there are no clear guidelines of how the information and the 3D-model should be transferred from the management team to the different disciplines and the workers at the construction site, even though there is an intranet where the existing 3D-model is available.

6.2 BIM in the construction phase

Another question, which was asked within this study, was “To what extent can, different disciplines at a construction site, use the information in a BIM model and what specific information is needed, according to the different disciplines?”. This question was asked to find out whether there are too much, or too little or if it is sufficient information in the model and also how the information can be used and for what purpose.

2D drawings have traditionally been the common information source at construction sites (Linderoth, 2013). This is reflected in the result and the different disciplines use the 2D drawings, up to several times per hour, to obtain information and details regarding the installations. To be able to use the 3D-model in a lager extent, the interviewees pointed out different functions and applications.

Several of the interviewees wanted the different disciplines work to be colour-coded and they want to be able to switch on and off the other disciplines work. These demands and modifications are something that is already possible to do in the 3D-model, but how this is done needs to be communicated to the workers.

The interviewees request a level of details which, according to Weygant (2011) should be represented by LOD 400. LOD 400 shows precise geometry including a higher amount of information regarding design, fabrication and assembling which, according to the different disciplines, are information which they use today from 2D drawings and its related documents. However, another finding from the interviews shows that electrician discipline often starts their installations in a later stage and at a time when the other disciplines already have performed their tasks. This, together with an assembly of several very detailed 2D drawings, could be the reason for why electrician discipline considers it difficult to see the benefits from BIM and the 3D-model. LOD 500 represent as-built which is how the different installations and element is modeled (Bedrick, 2008). Since the electrician discipline often starts their work after the other disciplines, LOD 500 might be needed. The other disciplines have similar perceptions regarding how detailed the 3D-model should be. In some situations a LOD 400 is required but in most cases a LOD 300 is sufficient, hence a LOD 350 could be a solution.

A lot of the installers and workers requested information, and how they want this information to be displayed, are already designed in the 3D-model. In the existing 3D-model different disciplines' installations are for example colour-coded. This enables distinction between the different discipline's components, which was a request that arose during the interviews. Since the existing 3D-model has been used for clash detection during the design phase, it indicates that dimensions are precisely defined, before the construction phase begins. Peab's third level, used during the design phase, is a 3D-model that matches the detailed construction documents. If this information is already included in the 3D-model, the focus should be on how this information could be accessed, by the installers and workers at the site, rather than on what additional information is needed.

The figure 5, in the chapter "Result and Analysis", displays that the information today is communicated from the management team and supervisor to the installers and workers, via a foreman. The interviews show that the supervisor is well-informed regarding BIM and the existing 3D-model, hence the installers and workers have not got any information from the foreman regarding the model, even if the 3D-model is accessible for all actors via the intranet. This indicates that the existing information is not communicated, rather than lack of information. One obstacle, mentioned during the interviews, was that later on there might be need for a new profession role. This professional role would be responsible for BIM, the 3D-model and the communication and information flow between all parties. A new professional role with the responsibility of communicating BIM within a project could solve the communication obstacle. Another solution could be clearer directives regarding each actor's responsibility of involvement in BIM and that coordination of BIM is included in the supervisors work.

Figure 6 visualise the existing information in the 3D-model, the top box, the information the interviewees use in the 3D-model today in the construction phase, the small middle box, and the figure also displays the information requested of the 3D-model, by the interviewees, bottom box. The size of the boxes illustrates the amount of information used in the different phases and as displayed in the figure the top box is the same size as the bottom box, which means that almost all requested information already exist. Hence a conclusion could be lack of communication.

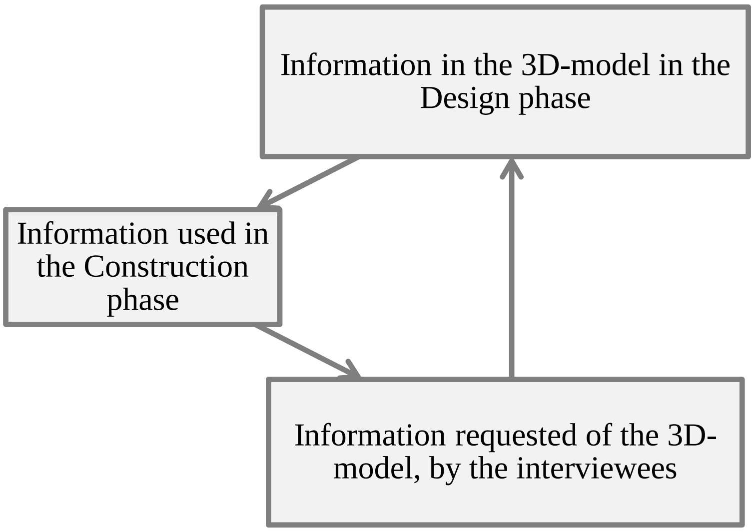


Figure 6: Information flow.

6.3 Obstacles and barriers to overcome

The third and last question "What are the obstacles when using BIM in the construction phase and what barriers must be conquered to enable a further development of BIM guidelines, to make BIM more suitable for the construction phase?" was asked to be able to link Peab's existing and future work with BIM.

From the theory there are many advantages by using BIM, for example processes are much faster and effective (Azhar, 2011), BIM also enhance the communication between the different actors in a construction project (Jongeling, 2008) and the documents, from the design phase are better suited for its purpose, which leads to a better construction phase. Few of these advantages were mentioned during the interviews, the main reason for this could be that the project did not meet the vision that the project should have 4D and 5D attributes. Another reason could be that the interviewees did not, from the beginning, know that it was a BIM project. Even though none of the overall advantages was mentioned during the interviews, the majority of the interviewees were aware of the benefits by having a 3D-model. But as Azhar (2011) writes in his article, there are many benefits by using a 3D visualisation model in a construction project, but BIM is also so much more than just a 3D-model.

One hindrance mentioned in the theory is the construction industry's unwillingness to change traditional work processes and reluctance to learn new concepts and technologies (Gu & London, 2010). In this case the result does not match the theory, in fact the interviewees where open to anything that could facilitate their work, but they saw BIM as a complement rather than a substitute to the existing drawings and its related documents.

Another point mentioned in the theory as a barrier to a broader use of BIM is that since few in the construction industry has experience of BIM, there is no explicit knowledge of what the industry need and require of BIM (Gu & London, 2010). This statement could be a an explanation to the answers given during the interviews, for example if one does not know what BIM is then it is quite hard to come up with what you expect from it. Concerning what other attributes the interviewees wanted in the 3D-model and the fact that the answers were restrained could also derive from the statement from the theory. Since the interviewees had not worked a lot with the 3D-model it could be hard to express what would make the model more useful.

According to the theory the willingness and interest of BIM is very important for further adoption of BIM (Xu, et al., 2013). Since all of the interviewees have a positive attitude towards new technologies which could facilitate their work, it is very good conditions for a wider use of BIM. The client of the Lyckholms project did not request BIM in the project and since a client of a construction project has a large impact of the spread of BIM adoption (Eastman, et al., 2011) involving the client in this case could have increased the use of BIM and its benefits.

7 Conclusion

The purpose of this study was to investigate how BIM can make the construction phase more effective and optimised, by transferring BIM information from the design phase into the production phase. The main finding is, by using BIM, the possibility to extract section drawings from the 3D-model and the possibility to let the workers decide which particular sections they need. In the traditional way, getting the supplementary section drawings is both time consuming and leads to additional costs. Another finding is that using a 3D-model at the construction site, for visualisation, facilitates the disciplines work through creating a common base for discussion and problem solving, hence creating a team spirit. This indicates a change from a drawing based construction phase to a model based, where the model is the main provider of information.

The objective in this study was to investigate the general knowledge of BIM amongst workers at the construction site and to identify the necessary information, which must be included in the BIM model, to make it useful. The identification should support the development of BIM guidelines for the production phase. Conclusions from the discussion are that a lot of the information requested, from workers, exist in the model, but is seldom communicated to the disciplines. If the requested information is already included in the 3D-model, the focus should be on how this information could be accessed, by the installers and workers at the site, rather than on what additional information is needed. Therefore recommendations could be clarification of strategies regarding how the information and the 3D-model should be transferred from the management team to the different disciplines and the workers at the construction site.

To integrate BIM in the construction phase clearer directives could be needed, regarding each actor's responsibility of involvement in BIM. To further integrate BIM and to solve the communication obstacle a new professional role with the responsibility of communicating BIM within a project could be beneficial. An alternative could be to develop the supervisor's role and include coordination of BIM. Another important aspect to enable the integration of BIM is to communicate the overall goal with BIM and not just to emphasise on details, such as LOD. Furthermore clarifying the benefits for all involved actors in the construction project is important for BIM integration, because if more people find BIM advantageous it will increase the likelihood of additional users adapting BIM.

As the result shows the communication flow is not sufficiently defined and an information gap, regarding the existences and the possibility to use BIM, occurs. Therefor a suggestion for further studies, concerning the integration of BIM in the construction phase, is the communication flow between the supervisor, foreman and worker.

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Appendix A

Interview questions

1. Berätta lite om dig själv och företaget du arbetar för

   (Tell us a little about yourself and the company you work for)
2. Vad har du för arbetsuppgifter?

   (What are included in your work?)
3. Hur länge har du arbetat med ”den” typen av arbetsuppgifter?

   (For how long have you worked with the same type of work?)
4. Vad använder du för information idag för att utföra dina aretsuppgifter?

   (What kind of information do you use to be able to execute your work?)
5. Hur långt innan du börjar dina arbetsuppgifter får du den informationa du behöver?

   (How long before your work begins do you get the information you need?)
6. Använder du någon gång information från andra yrkesgrupper?

   (Do you ever use information from other disciplines?)

   a. För att sätta er in bygget som helhet?

      (To get an over view?)

   b. För att lösa just era arbetsuppgifter?

      (To solve your work?)
7. Finns det någon information du saknar som skulle kunna underlätta dina aretsuppgifter?

   (Is there any information you do not get, that would facilitate your work?)

   a. Hur ska den i så fall redovisas?

      (In case there is, how would you like it to be presented to you?)
8. Får du för mycket information?

   (Do you get too much information?)

   a. I så fall vad?

      (In case, what information is that?)
9. Vad har du för kunskaper om BIM och vad BIM innebär?

   (What kind of knowledge do you have of BIM and the concept BIM?)
10. Vad är dina erfarenheter av BIM?

    (What experiences do you have of BIM?)

    a. Har du tidigare deltagit i något ”uttalat" BIM projekt?

       (Have you worked in a BIM project earlier?)

b. Om ja: Vad såg du för fördelar/nackdelar?

(If yes: Which advantages/disadvantages did you experience?)

11. Har du använt BIM någon gång?

    (Have you ever used BIM?)

    a. Föra att få korrekt information inför dina arbetsuppgifter?

    (To get the correct information for your work?)

    b. Eller till vad?

    (Or what else?)

    c. Om du inte har testat har du hört någon som har använt det och vad tyckte dem?

    (If you have not tested BIM, have you heard from anyone that have used it and what did they think?)

12. Kommer du i detta projekt använda dig av 3D modellen i första hand? eller vilka dokument och ritningar kommer du att nyttja?

    (In this project, will you mainly use the 3D-model? Or which drawings and its related documents will you use?)

→ Se 3D modellen i visualiseringsglasögonen

(Watch the 3D model in the head mounted display)

13. Baserat på det du kan om BIM och nu har fått känna på, tror du att du skulle kunna ha några fördelar av att använda det för dina arbetsuppgifter?

    (Based on what you know about BIM and what you just experienced with the head mounted display, do you think you would have any advantages by using this to execute your work?)

14. Nu när du har du sett modellen över Lyckholms:

    (Now when you have seen the 3D model of Lyckholms:)

    a. Vad är det för information i modellen som du använder?

    (Which information in the model do you use?)

    b. Vad är det för information i modellen du saknar och skulle behöva för att lösa dina arbetsuppgifter?

    (Which information, in the model do you miss and would need to execute you work?)

   i. Hur ska den i så fall redovisas?

      (*In case, how would you like it to be presented?)*

c. Får du för mycket information?

   (Is there too much information?)

   i. I så fall vad?

      (In case, which information?)

d. Hur skulle du vilja ”jobba” i denna världen (är laser-pekaren bra?)?

   (How would you like to ”work” in this 3D world (do you like the handheld device?)?