Possibilities with BIM in relation to cost estimation and scheduling

A case study of a Swedish civil engineering project

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

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Master's Thesis 2014:121

MASTER’S THESIS 2014:121

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Chalmers reproservice / Department of Civil and Environmental Engineering
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ABSTRACT

The construction industry is characterized by its project-based nature with many actors and stakeholders in every part of a project. These actors have different ways of expressing themselves, they use different software, and they produce and handle large quantities of documents. This has created "information islands" where information has to be reinterpreted and restructured to fit different people and software, causing duplication and loss of information at each stage of a project. Some people think that using BIM, mostly referred to as Building Information Modelling, is one way to close the information gaps and create one source of information instead of many. The purpose of this Master's Thesis is to investigate the possibilities of BIM, the implementation difficulties, and the use today from the perspective of a contractor. The research focuses on the coordination between design, scheduling, and cost estimations. In order to gain knowledge of current working processes a case study has been performed and a reference project has been studied. Interviews have been carried out with people involved in the design, scheduling, and cost estimation. To understand how BIM is used and what the implementation difficulties are, interviews have also been held with the BIM department at the reference company. The case study has shown that both cost estimations and schedules are dependent on quantity information from the design and that BIM can be used to make model-based quantity take-off. However, this process does not in itself create any automated information sharing, but is based on exports and imports where manual intervention is needed. Another way to connect estimating and scheduling to a model is to do the planning work inside BIM software. However, this might not be an optimal solution for the reference company today since they use an internal software called Spik for estimations. One consequence of performing planning work inside BIM software is that many people from different disciplines need access to the same model, which creates several difficulties. Instead a database solution is recommended where objects, such as building parts, are handled in a 3D model but the information is stored in the database and connected to the model in an intelligent way. The case study also shows that there are many barriers that hinder an effective implementation of BIM. These are mainly connected to the lack of industry-wide standards and knowledge on how to implement and use BIM. This has created a situation where companies need to create their own solutions. To enable an efficient and effective collaboration with the use of BIM, it is vital that standards are established. Otherwise many different solutions will be created and used within different companies and the development towards efficient industry-wide collaboration will move slower.

Key words: BIM, cost estimation, scheduling, design, quantities

Möjligheter med BIM I samband med planering och kalkyl
En fallstudie på ett svenskt anläggningsprojekt
Examensarbete inom Design and Construction Project Management
FREDRIK KULLVÉN, KATRINE NYBERG
Institutionen för bygg- och miljöteknik
Avdelningen för Construction Management
Chalmers tekniska högskola

SAMMANFATTNING

Byggbranschen kännetecknas av sin projektbaserade natur där många aktörer och intressenter är delaktiga i alla skeden av ett projekt. Dessa aktörer har olika sätt att uttrycka sig, de använder olika programvaror, och de producerar och hanterar stora mängder dokument. Detta har skapat "informationsöar" där information måste omtolkas och omstruktureras för att passa olika människor och mjukvaror, vilket orsakar dubbelarbete och förlust av information i varje skede av ett projekt. Vissa tror att användandet av BIM, oftast kallat Building Information Modelling, är ett sätt att koppla ihop informationen och skapa en källa av information istället för många. Syftet med denna masteruppsats är att undersöka möjligheterna med BIM, svårigheterna med implementeringen, och användandet i dagsläget utifrån en byggentreprenörs perspektiv. Studien är inriktad på samordningen mellan projektering, tidsplanering, och kalkyl. För att få kunskap om nuvarande arbetsprocesser har en fallstudie genomförts och ett referensprojekt har studerats. Intervjuer har genomförts med personer som deltar i projekteringen, tidsplaneringen och kalkyleringen. För att förstå hur BIM används och vilka svårigheter som är kopplade till implementeringen har intervjuer också genomförts med BIM-avdelningen vid referensföretaget. Fallstudien visar att både kalkyl och tidsplanering är beroende av mängder från projekteringen och att BIM kan användas för att göra modellbaserade mängdavtagningar. Denna process skapar dock ingen automatiserad informationsdelning i sig, utan kräver export och import och en hel del handpåläggning. Ett annat sätt att koppla ihop kalkyl och tidsplanering med en modell är att utföra arbetet i BIM-programvara. Dock kanske detta inte är en optimal lösning för referensföretaget i dagsläget eftersom de använder en intern programvara som heter Spik för kalkylarbetet. En konsekvens av att utföra planeringsarbete såsom kalkyl och tidsplanering i BIM-programvara är att många personer från olika discipliner behöver tillgång till samma modell, vilket ger flera negativa följder. Istället rekommenderas en databaslösning där objekt, såsom byggnadsdelar, hanteras i en 3D-modell, men där informationen lagras i databasen och kopplas till modellen på ett intelligent sätt. Fallstudien visar också att det finns många hinder för en effektiv implementering. Dessa är främst kopplade till bristen på branschövergripande standarder och kunskap om hur man kan implementera och använda BIM, vilket har lett till en situation där företagen behöver skapa sina egna lösningar. För att möjliggöra ett effektivt samarbete genom användningen av BIM är det viktigt att standarder fastställs. Annars kommer många olika lösningar skapas och användas inom olika företag och utvecklingen mot ett effektivt branschövergripande samarbete kommer att gå långsammare.

Nyckelord: BIM, kalkyl, tidsplanering, projektering, mängder

Contents

Preface

This Master Thesis has been conducted full time during the spring of 2014 and completes our education in Civil engineering at Chalmers University of Technology.

We would like to thank the interviewed employees at Skanska Sweden AB for contributing during our time at the company. You have always supported us and been available for follow up questions and discussions.

We would especially like to thank our mentors, Per-Ola Svahn at Skanska and Christian Koch at Chalmers for your constructive comments on our work. Your commitment and help has been highly significant to us when performing our work.

Göteborg July 2014

Fredrik Kullvén and Katrine Nyberg

Notations

3D – Three dimensional

4D – Four dimensional

5D – Five dimensional

BIM – Building Information Model/Building Information Modelling/Building Information Management

CAD – Computer Aided Design

IFC – Industry Foundation Classes

IT – Information Technology

ICT – Information and Communication Technology

SEK – Swedish crones

SMB – South Marieholm Bridge

1 Introduction

In this chapter the thesis background is presented in order to define the knowledge gap from which the research is based. Furthermore, the thesis purpose and research questions are presented.

1.1 Background

The architecture, engineering and construction (AEC) industry is characterized by its project based nature, which makes standardization difficult. There are many actors and stakeholders involved in every part of a project, and typically there are not enough incentives for these actors to work towards common goals, such as low operation and maintenance costs. Instead they focus on their own work, trying to optimize their own results (Svensk Byggtjänst, 2013). Furthermore, all actors have different ways of expressing themselves and denominate things, and depending on their field of profession and preferences they also use different software. This has created a situation where information needs to be reinterpreted and restructured to fit different software and be understood by different people when transferred (Svensk Byggtjänst, 2013).

In the traditional analogue construction industry big quantities of documents such as drawings, quantity lists, and technical specifications are handled. Because of the fact that these origin from different sources and are created by different actors there is high risk for conflicting information. Today it is even assumed that there will be conflicting information, which is why there is a hierarchy between documents included in the standard form contracts (Svensk Byggtjänst, 2013).

The combination of many actors and big quantities of documents has created “information islands”, where information is reconstructed at each stage of a project and for each project, causing duplication and loss of information (Mehrvash and Yasin Tarid, 2013). There is a big need to connect these islands and create one source of information instead of many. Using BIM, most commonly referred to as building information modelling, is one strategy to close the information gaps. A BIM model is an object-based 3D model where information is connected to the objects in order to facilitate information sharing between the different phases and actors of a construction project (Lindström, 2013). The vision with BIM is that information only should need to be entered once and in one place, with the ability to be handled by different actors in an unbroken chain of information (Svensk Byggtjänst, 2013). But even if BIM in theory present a very big potential for supporting information handling, the reality show that the implementation is far from complete. For example there is no fully established process to make sure that cost estimations or time planning reflects what is happening in the model (Svensk Byggtjänst, 2013). Furthermore, BIM has mostly been associated with house construction and used in a lesser extent in civil projects. Lack of industry standards and BIM guidelines, poor interoperability between software, insufficient knowledge, and slow organizational changes make the full implementation complicated.

1.2 Purpose

The purpose of this Master’s Thesis is to investigate what possibilities that exist when using BIM processes, what difficulties that arise when implementing BIM and how it is used today from the perspective of a contractor. The research takes its point of departure in information sharing in and between different phases of a project, focusing on the coordination between design, scheduling, and cost estimations. One ongoing civil engineering project is examined in order to understand how current working processes in the Swedish civil engineering sector today. At the reference company there is a vision to gradually implement applications of BIM in civil engineering projects. Today some of the defined applications can be used in a satisfactory way, but it is a long process left before the whole chain of information is connected. Two of the undeveloped applications of BIM are cost estimations and time scheduling. The thesis investigates the possibilities with model-based scheduling and cost estimations, along with barriers that hinder an effective implementation of BIM. The research will also examine what type of information and how much information that is needed in a model in order for it to be useful in connection to time scheduling and cost estimations.

1.3 Research questions

- How can BIM be used in relation to cost estimating and scheduling?
- What requirements need to be put on a model in order for both cost estimating and scheduling to benefit from it?
- What are the main barriers that hinder an effective implementation of BIM in connection to cost estimating and scheduling?

2 Theoretical frame of understanding

To understand the complexity of large organizations and the context in which civil projects are situated, an overview of this is presented in this chapter. First, general aspects of organizational coordination in large organizations are presented. Then the building process and its complexity are explained. After this, the development within the construction and civil industry from 2D-drawings to BIM is described. Furthermore, the applications, limitations and challenges of implementing BIM are outlined. The theoretical frame of understanding has the purpose of supporting the discussion and the concluding remarks of this thesis.

2.1 Organizational coordination

According to Hemphill (2009), coordination refers to management that enables effective work. This includes synchronization and integration of activities, responsibilities, as well as command and control structures to ensure that resources are used in the most efficient way. Furthermore, to facilitate the development of effective coordination strategies and structures, a greater understanding of successful collaboration between specialists is necessary. Collaboration is a way to solve problems that are too large or complicated for a single entity to solve on its own and refers to the process of collaboration as well as the activities of collaborating (Hemphill, 2009). Furthermore, successful collaboration requires compromise and presents challenges of communication and coordination.

To carry through a complex task, Mintzsberg (1983) explains that any project group always faces two conflicting demands. The first one is the dividing of one task into smaller tasks in order to support specialization, and the second one is to coordinate the subtasks in an accurate way to accomplish the beginning task.

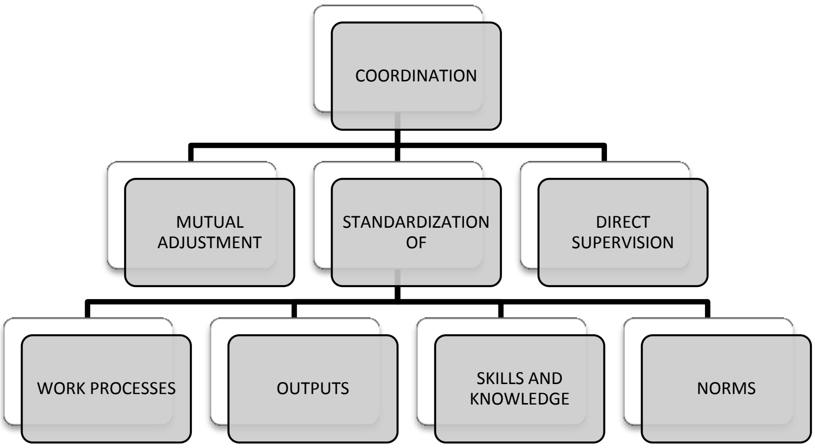


Figure 1: Mintzbergs' six coordination mechanisms.

Furthernore Mintzberg (1983) defines six mechanisms (Figure 1) regarding the coordination between different tasks. These mechanisms have the goal to achieve coordination.

- Mutual adjustment: collaboration between project participants in terms of informal communication is necessary between people performing co-dependent work tasks.
- Standardization of work processes: specifications of how a process or task is conducted enables for coordination.

- Standardization of output: specifications about expected results are made rather than how to accomplish the task.
- Standardization of skills and knowledge: specified training and education to make sure expectations of performances is established, e.g. the almost automatic coordination between doctors in an operation room.
- Standardization of norms: social constructions establish common values and beliefs to make sure people are working towards the same expectation.
- Direct supervision: when one person is responsible for the work of several people and has the authority to issue orders or instructions to these people.

According to Hemphill (2009), literature on efficient collaboration mainly reasons about the importance and the difficulty of achieving it. Many models explain the *what* of collaboration; e.g. coordination, common goals, but not *how* to actually realize it. Hemphill (2009) also emphasizes the importance of understanding what set of capabilities teams have to adjust to unexpected events.

Interorganizational coordination, including projects, often involves entities that have different expertise. One aspect that Hemphill (2009) concludes is that positive relations in a team are vital to enable for successful results. Without respect, understanding and recognition for each other's work, the gain of common goals, organizational structures and strategies may be minimal. Thus, focusing on managing interpersonal relationships in the project team, like developing trust and concern for one another rather than how projects should be managed at the project level (when should what get done, who should do it, to whom should someone report) would make sense according to Hemphill (2009).

2.1.1 Information sharing

Information sharing describes the exchange of data between various organizations, people and technologies. Sharing of information can according to the Project Management Institute (2014), be divided into three categories; pull, push, and interactive information sharing.

Pull information sharing can be described as information on a server or similar, which is possible to retrieve when needed. This type of communication is used for large volumes of information or for reaching many readers. Examples are information stored on a website or documents saved to a joint server. It can also be a blog with company or project news (Project management institute, 2014).

Push information sharing is when information is sent to a specific person via e-mail, text messages, letters, or similar. This way of receiving information is not as optional as with pull information sharing. Furthermore, this type of communication does not ensure that the information has reached the person it was sent to or that it was understood (Project management institute, 2014).

Interactive information sharing means that the communication is taking place in real time where all participants can reply and ask questions directly. This ensures that all people receive the information needed. The communication can be delivered via phone, face to face, video call, or similar (Project management institute, 2014).

2.1.2 Managing organizational change

Zastrow and Kirst-Ashman (2007) define an organization as social unit intentionally constructed and coordinated to meet specific goals. Change in an organization means that the entity shall move from the present situation to a desired state (Lillemets, 2010). According to Zastrow and Kirst-Ashman (2007) this is necessary in order for the organization to grow and meet the changing environment in our society.

Lillements (2010) says that to be successful in changing an organization it is necessary to, in a structured and planned manner, involve and engage the employees affected by the change. Lillements (2010) also states that it is essential that the employees have a chance to be involved early on in the work towards change. This is because much of the work to engage people is about gaining an understanding of individuals' work and what is important to them. It is also important to realise that the set of skills and experiences are as many as the number of employees. With this knowledge as a base for change, goals and part goals can be set and by communicating this to individuals they can get a sense of participation and be motivated to adapt (Lillemets, 2010).

Bacharach (2013) pinpoint three challenges for organizations working with change. One of them is the rigidity of structure. All organizational structures become rigid with time, which makes the ability to change hard. People grow accustom to a certain way of performing tasks and within an organization this could lead to a structure of tunnel vision were e.g. departments isolate from other departments. The second challenge is the uncertainty when implementing change. If changes are implemented in an organization and fails, money may be lost. The fear of losing a great deal of money is the biggest incentive not to act at all. Lastly, a change which may risk contractual agreements and can lead to losing clients intimidates organization from changing (Bacharach, 2013).

Fors-Andrée (2014) says that when working with changes in large organizations, some challenges are recurring. One challenge is if one strong department has its own agenda and has a hard time to cooperate outside of the department, excluding others, which make effective collaboration hard. Another challenge is if the culture is characterized by prestige where e.g. different support functions compete about resources or blame other functions in the organization of being responsible for recurring problems. Furthermore, since all people in an organization are busy dealing with their everyday tasks, they can have a hard time understanding the big picture. Fors-Andrée (2014) means that this can be related to the convenience of individuals. It is easier to focus on individual tasks then to deal with larger issues. Moreover, a related challenge is that departments of expertise naturally focus on their tasks and find it hard to understand the organization from other specialists' perspectives. Moreover, large organizations are often policy-driven, which makes some people avoid dealing with a problem in order not to risk performing in a way that could break a corporate policy. In other words, people shy away from responsibility to avoid making mistakes (Fors-Andrée, 2014). Additionally, the uncertainty in change causes organizations to wait for other organizations to try out new technology or processes and wait for the results. To perform in a familiar way is more appealing than to risk trying new ways.

2.2 The building process

A construction project includes many actors, resources and not least a massive flow of information distributed among the actors. It is not easy to manage such a large number of people and documents, regardless of the contractual approach taken (Eastman, 2011). Furthermore, this complexity makes it important to manage information in a satisfying, accurate way. Even though the building process can be organized in several different ways, some activities are in most cases included (Nordstrand, 2008).

Those activities are design, production, and maintenance. Moreover, the process is often complicated and can be considered from several angles depending on what role a person has in a specific project. The term construction relates to everything from houses to bridges, but there is a distinction between house construction and civil engineering (Gustavsson, 2006). House construction generally refers to houses and buildings and civil engineering relates to bridges, roads, airfields, harbours, power plants, tunnels, sewers and more. In this chapter the actors involved in the building process will be presented as well as the main activities of the process.

2.2.1 Actors

The initiative to start a construction project is taken by the owner who will also own the end product (Nordstrand, 2008). Furthermore, the owner is the person or entity on whose account the project is planned and produced, and who is responsible for the funding. When the project is started, an architect is most often responsible for designing the building or structure in an aesthetically pleasing and functional way, making sure that the end product will be suitable for the activities that it will be used for (Nordstrand, 2008). Structural engineers perform strength and sizing calculations for the load-bearing structural components (Gustavsson, 2006). A structural engineer is also responsible for ensuring that the construction is protected against cold, heat, water, moisture, fire and noise in the best way. In addition to the architect and structural engineer there are other technical consultants involved in the design stage, such as geotechnical consultants, acoustic consultants, and HVAC consultants.

A construction contractor is responsible for the whole or parts of the construction work on behalf of the owner (Nordstrand, 2008). Moreover, there are usually several contractors involved and responsible for different parts of the construction. The different contractors are actors such as construction companies, plumbers, electricians, and painters (Gustavsson, 2006). Material manufacturers and suppliers are also important in the production stage since building materials usually accounts for half of the production costs.

In addition to actors who are in direct contact with a construction project there are many other stakeholders with various degree of interest in the project. These could for example be municipalities that control areas through detailed planning or people who live close to the construction site and are affected by the production (Olander, 2006). These stakeholders need to be managed properly in relation to how much power and interest they have in the project. Figure 2 illustrates the various actors involved in a typical building process and their organizational boundaries (Eastman, 2011).

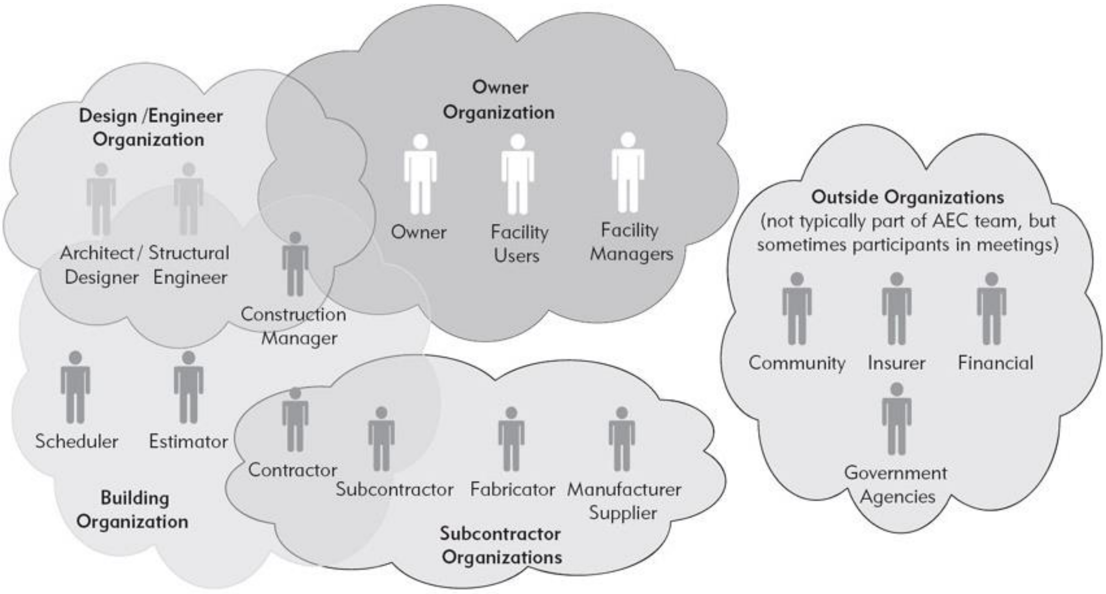


Figure 2: Illustration of actors in a building process and their organizational boundaries. Source: Eastman (2011).

2.2.2 Procurement and tendering

The act of procuring refers to the purchase of goods or services, such as services from consultants, activities from contractors, or materials from suppliers (Gustavsson, 2006). Procurement can take place at any time during the construction process depending on the used contractual method and normally there are two main actors in a procurement process, a client and a contractor (Berglund and Emanuelsson, 2013). The most common contractual agreements in Sweden are Design-Build (Figure 3), and Design-Bid-Build contract (Figure 4) (Molin and Spoof 2006). In the design-build arrangement, the contractor is responsible for both the design and construction of a building project. The client specifies how the facility should look and what it should contain with for example simple sketches and descriptions. Additionally, the owner specifies requirements on what functions the facility should have. In a design-bid-build contract on the other hand, the client contracts with separate companies for the design and construction of a project and is responsible to provide the contractor with finished construction documents (Molin and Spoof 2006).

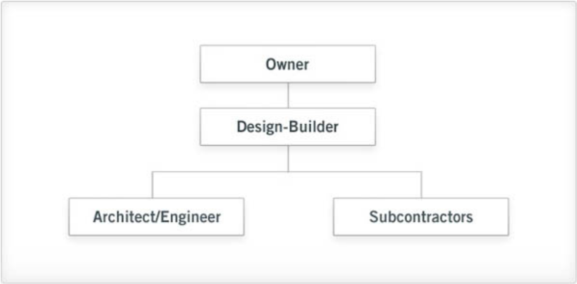


Figure 3: Design-Build. Source: Keybuilders Construction (2014).

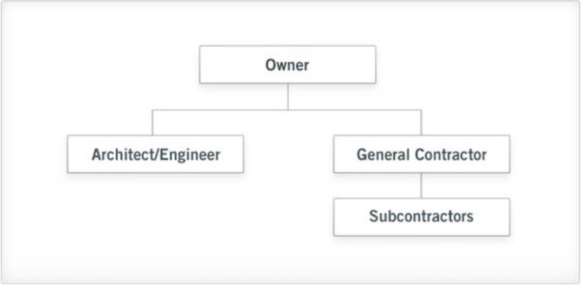


Figure 4: Design-Bid-Build. Source: Keybuilders Construction (2014).

The first stage of a procurement process is that the client produces tender documents that include technical specifications and project-specific conditions (Berglund and Emanuelsson, 2013). In order to select the most suitable price, the client initiates the tendering process by inviting competing contractors to estimate a price based on the tender documents. When the contractors present their prices the client choose one of them based on price and fulfilment of requirements (Berglund and Emanuelsson, 2013). The selected contractor then gets to sign a contract with the client.

If the client is a public entity, the procurement needs to be in accordance with *The Swedish Public Procurement Act* (SPPA) (Fryksdahl and Jounge, 2012). SPPA state that the winning tender should be the most economically favourable (Berglund and Emanuelsson, 2013). This is to facilitate equal rights for all involved contractors and to increase competitiveness between them. If the client considers other aspects than lowest price this needs to be stated in the tender documents (Berglund and Emanuelsson, 2013).

In the tendering stage contractors compete for the opportunity to design and build a construction. This is a very time consuming process connected to high risks and difficult cost estimations (Berglund and Emanuelsson, 2013). Furthermore, to improve the chance of receiving enough projects, a contractor needs to work on more than one tender at a time. The aim for the contractor is to establish a competitive bid price in order to get the job and at the same time keep the price high enough to be able to make a profit from the project (Berglund and Emanuelsson, 2013). When working on a bid the contractor needs to use professional experiences to make rough estimations of needed workforce, machines, material costs, costs for subcontractors etc. Furthermore, overhead costs such as interests, administration, and profit needs to be included. In order to do this many different actors within the company are involved during the tender. Some of the commonly included professionals are estimators, project managers, design engineers, and construction managers (Berglund and Emanuelsson, 2013).

2.2.3 Design

The design phase aims to generate technical specifications and drawings needed in the production (Berglund and Emanuelsson, 2013). This work is done in different stages and starts early in the project by investigating possibilities in relation to the function of the construction and quality demands from the owner. When possibilities have been evaluated, the construction's other appearances is decided and visualized (Nordstrand, 2008). In this stage, construction and installation systems are decided and displayed in system documents. These documents are needed when applying for building permits. Lastly, dimensions, measurements, material and decoration choices are made to complete the finished construction documents (Nordstrand, 2008). The construction documents therefore consist of drawings and descriptions needed for cost estimations, production, and maintenance.

2.2.4 Quantity take-off

Quantity take-off regards detailed measurements of materials and labour needed to produce a construction. Furthermore, time scheduling and cost estimations are both based on quantity information regarding e.g. building parts, materials, surfaces, and volumes. Today most quantity information is produced manually from 2D drawings, meaning that drawings are measured in order to calculate the quantities (Jongeling, 2008). This process is time consuming, and there is a risk for mistakes, which can lead to inaccurate quantity information. However, there are programs that can extract quantity information from a model and transfer it to e.g. cost estimation programs. This can save time and the information is also very accurate (Bengtsson and Jauernig, 2008). Alternatives for making quantity take-offs with the help of models are presented in chapter 2.5.4.

2.2.5 Cost estimation

It is vital for a construction contractor to make realistic project cost estimations during the tender stage. In order to make the estimation as realistic as possible, the estimator needs to have a good understanding of the project and good knowledge of production costs (Bengtsson and Jauernig, 2008). This knowledge is often obtained through professional experience and cost estimations from earlier projects. Cost estimation includes both direct costs, such as construction materials, and indirect costs, such as insurance, electricity, and waste disposal (Bengtsson and Jauernig, 2008). Additionally, costs for the use of central administration resources are added together with a margin covering other administrative costs and profit. All these costs combined form a bid price, or in other words the amount of money that the contractor will charge to perform the construction.

Since the computer was introduced in the 1980s the way to do cost estimations has been substantially developed (Bengtsson and Jauernig, 2008). The development has progressed from only working manually with paper, pen and large amounts of documents, to gathering the information in a clear and informative structure in a computer program. With the information managed this way it is easier to find errors and it is also less time consuming (Bengtsson and Jauernig, 2008). Today many companies have developed their own calculation programs to suit their business. An example is Spik, a calculation program as well as information management system, that is developed and used by Skanska (Ajani and Karaömer, 2010).

2.2.6 Scheduling

In order to reach and control a business goal, a realistic main schedule is required (Nordstrand, 2008). The purpose of this is to seek the best way to perform the project by allocating resources and planning for the length of activities and for the logical sequence between them. Different input is used for estimating the duration of tasks depending on which stage the project is in and how detailed the design information is (Tulke et al, 2008). In early stages the input mostly consists of experience from earlier projects. Precise planning can only be done once detailed design information is available. Often general project management software such as MS project, Primavera, or Asta are used to create the schedule (Tulke et al, 2008).

The traditional way of planning the production process is by using 2D drawings, sketches, Gantt-charts, forecasts, etc., and information from several disciplines needs to be included in the schedule (Jongeling, 2008). Furthermore, it is common that the design process is not finished but proceeds parallel to the planning and production, making these processes even more complicated. Coordination difficulties and information misinterpretations often mean that problems need to be solved during the production (Jongeling, 2008). This can result in production downtime, increased costs, incorrect assemblies, and quality compromises.

2.2.7 Production

The purpose of the production process is to build in accordance with drawings, descriptions, laws and regulations, standards, production plans, and budgets (Gustavsson, 2006). Before the construction starts, several different plans are developed. These together with the project budget represent a production program, intended to guide the work. Furthermore, in order to save time and resources, it is not uncommon that the production starts before the design is fully completed (Berglund and Emanuelsson, 2013). In order to steer the project towards the set up goals it is important to follow the plans and monitor the process (Nordstrand, 2008). The monitoring is conducted by comparing actual costs and spent time to budgeted costs and time. If deviations occur, they must be analysed to perceive how they affect the future of the project and to determine if any actions need to be taken (Gustavsson, 2006). For example, if the schedule cannot be followed, more resources may need to be allocated or the schedule needs to be revised.

2.2.8 Maintenance

The last part of the building process is maintenance, which starts as the production is finished and the product is delivered to its owner to be used for its intended purposes (Nordstrand, 2008). Maintenance includes administration, such as planning, managing, and monitoring the operation, as well as preservation of the facility.

2.3 Computer Aided Design

Computer Aided Design (CAD) is software for drawing and documentation and has been in use for over 20 years (Teicholz, 2013). It has developed from being a tool used for creating 2D drawings to being used as a tool for visualization in 3D.

When designing in 2D, architects and engineering consultants often produce 2D sections that describe the project in terms of storey heights or façade design, but also to visualize complex parts of the project, such as stairwells or fan rooms (Jongeling, 2008). The drawings are created by 2D-lines and symbols, and they describe the same building parts from different angles. In fact, to describe a certain building part with 2D tools it might be needed to produce 6-8 different drawings (Lindström, 2013). The two-dimensional drawings represent objects that in reality exist in three dimensions, meaning that a person has to imagine the objects in 3D based on 2D material. This creates a significant source of error since people can interpret the drawings in differing ways depending on aspects such as experience (Gustafsson, 2006). These interpretation issues and difficulties to visualize objects in three dimensions make it hard to understand the big picture and to discuss the object with other actors involved.

From the drawings, different lists and descriptions are set up to describe the project's content. This work is often performed manually with hand calculations to, for example, describe quantities of different building parts (Jongeling, 2008). One of the major disadvantages of 2D-CAD is that drawings are not connected to each other, meaning that when revisions are made to some part of a model, all the related drawings need to be changed (Jongeling, 2008). But not only drawings are affected; also quantity lists, cost estimations, production plans, etc. Furthermore, changes do not only affect one actor in most cases. These issues make the revision process time consuming and sensitive to errors.

Along with the development in computer capacity, the drawing technology has, as mentioned earlier, improved from 2D CAD into 3D CAD (Nilsson and Mårtensson, 2009). Older CAD systems produce plotted drawings, generated files that consist primarily of vectors, associated line-types, and layer identifications (Eastman et al, 2011). As these systems have been further developed, additional information has been added to these files to allow for blocks of data and associated text. With the introduction of 3D modelling, advanced definition and complex surfacing tools were added (Eastman et al, 2011). But even if software is becoming increasingly sophisticated and specialized for many disciplines within the construction industry, they have mostly been used to produce 2D drawings (Nilsson and Mårtensson, 2009). As CAD systems became more intelligent and more users wanted to share data associated with a given design, the focus shifted from drawings and 3D images to the data itself (Eastman et al, 2011). This has then developed into BIM, or most commonly referred to as Building Information Modelling.

2.4 Building Information Modelling

In the architecture, engineering, and construction (AEC) industry, companies and authorities has for a long time tried to decrease project cost, increase productivity and quality, and reduce project delivery time. Azhar (2012) mean that BIM is one potential way to achieve these goals and he describes BIM as an innovative way to virtually design and manage projects, which greatly improves predictability of building performance and operation. Reports on the possibilities of BIM to transform processes in the AEC industry were first visible as early as in the late 1980s and beginning of the 1990s (Linderoth, 2010). Despite this, the definition of BIM is still somewhat unclear. There are three common translations to the abbreviation BIM; *building information model*, *building information modelling*, and *building information management* (Lindström, 2013).

A *building information model* differs from a conventional 3D model in the way that it is built up by objects (Jongeling, 2008). These objects, e.g. building parts, relate to each other in the model and contain different information (Lindström, 2013). Figure 5 illustrates the difference between CAD objects and BIM objects. Examples of object information that can be included are geometry, spatial relationships, geographic information, quantities and object properties such as material, weight, colour, unit cost, and assembly time (Azhar, 2012). Based on this information cost estimates, project schedules, and quantity lists can be created (Lindström, 2013). Furthermore, changes in the model will be transferred to all documents generated from the model (Qing et al, 2014). Many 3D models are only created to visualize surfaces and are not built in the same intelligent way as a BIM model. But this is not to say that a BIM model cannot be the basis for 3D visualization used for attractive pictures and environments (Jongeling, 2008).

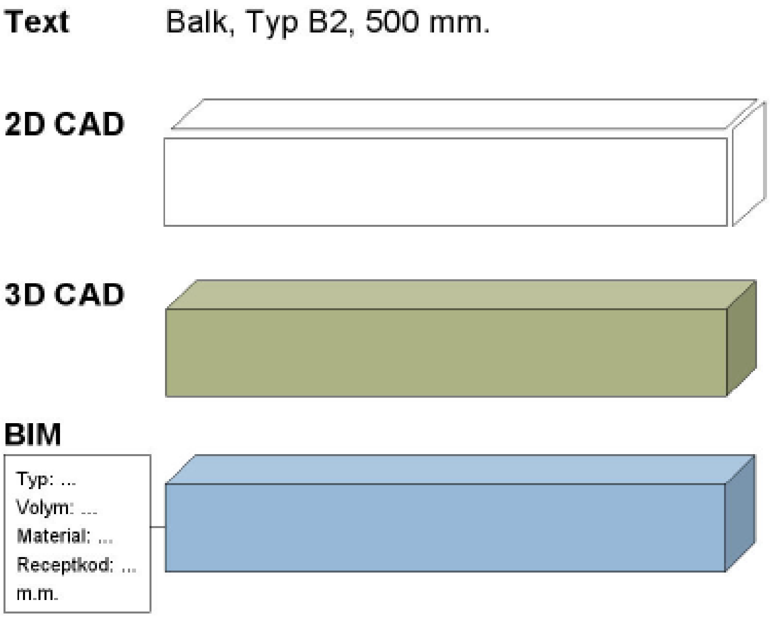


Figure 5: Illustration of the difference between CAD objects and BIM objects. Source: Bengtsson and Jauernig (2008).

Building information modelling refers to a process rather than the technology or model itself. It is a way of thinking and coordinating projects. One or several joint databases are used for collaboration where changes in one part of the database is transferred to all other parts and information is stored and can be reuse (Qing et al, 2014). The National Building Information Modelling Standard (NBIMS, 2007) describes the vision for BIM. The vision is "an improved planning, design, construction, operation, and maintenance process using a standardized machine-readable information model for each facility, new or old, which contains all appropriate information, created or gathered about that facility in a format useable by all throughout its lifecycle". Figure 6 illustrates the vision to connect information throughout the entire project lifecycle with the help of BIM.

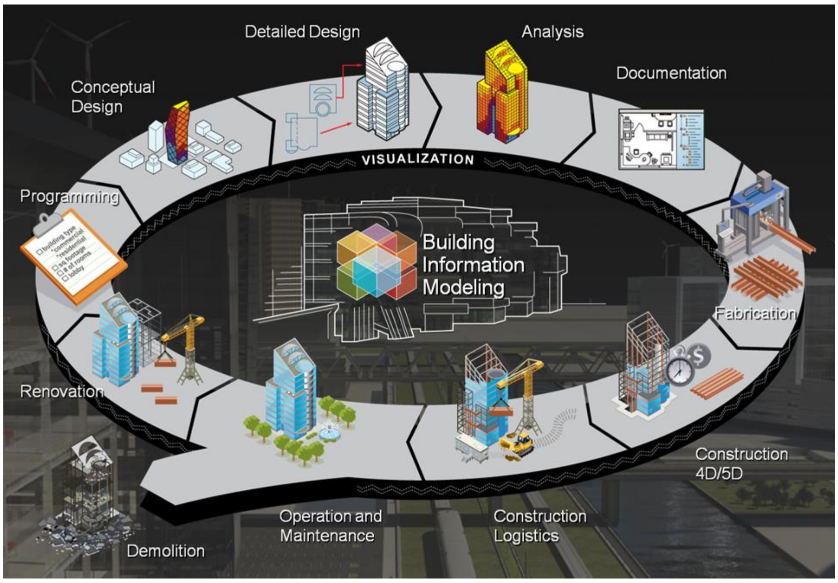


Figure 6: Connecting information throughout the project lifecycle with the help of BIM. Source: Buildipedia (2010).

Building information management is a name that is used in order to put BIM in a larger context and focus more on the information management from start to finish rather than the modelling itself (Skanska, 2014). The aim is to enable smart information handling and more efficient building projects by collecting all information in one place, thus creating an unbroken chain of information throughout the projects (Skanska, 2014).

2.5 Benefits and Applications of BIM

The benefits of BIM are discussed extensively in literature and the industry. Azhar (2012) implies that if used in a greater extent, BIM will lead to a higher level of collaboration in teams which will give higher profitability, reduced costs, better time management, and better customer-client relationships. This is supported by Bryde et al (2013) that through performed case studies conclude that the most positively improved aspects from the implementation of BIM is cost management, time management, communication, coordination, and quality management. Furthermore, Olofsson et al (2008) state that all stakeholders gain from BIM, but that it in the end is the client who benefits the most. Therefore the process should be evaluated on project level and costs and benefits should be shared among all actors. This is also the opinion of Dehlin and Olofsson (2008) that argue that the most benefits of BIM will be available if focus is on costs and benefits for the project instead of for individual stakeholders.

In recent past, BIM has mostly been associated with house construction, whereas the adoption of BIM in civil projects has been lagging behind (Mehrvash and Yasin Tarid, 2013). However, it has started to appear examples of Swedish projects where BIM are or will be used in greater extent. For instance, in a large infrastructure project called *Förbifart Stockholm*, a large proportion of the tender documents will be delivered in the form of models instead of traditional drawings (Trafikverket, 2014).

2.5.1 Visualization

One of the basic applications of BIM is visualization through 3D models (Viklund, 2011). This increases understanding among actors and can be helpful in the tendering stage since designers can get a better picture of the project scope and characteristics (Viklund, 2011). Furthermore, the craftsmen can better understand what should be done in each phase of the production. Figure 7 illustrates an example of a visualized bridge.

Figure 7: Visualization of a bridge. Source: Fundala et al, (2009).

2.5.2 Clash detection

Because of the large number of actors from different disciplines in construction projects, it is a demanding task to make sure that all parts of a structure fit together (Lindström, 2013). Since BIM models are designed to scale, all parts of a structure can be checked for interferences, making sure that for example pipes do not collide with beams or ducts (BIM Journal, 2012). Today these types of clash detections can be conducted automatically with software that alerts when systems collide (Jongeling, 2008). To conduct clash detection is nothing new, but with BIM modelling this process is done in the design stage rather than during production. Finding these inconsistencies is vital as they would severely impact the construction process, causing delays, design changes, and materials costs (BIM Journal, 2012). Figure 8 shows an example of clash detection.

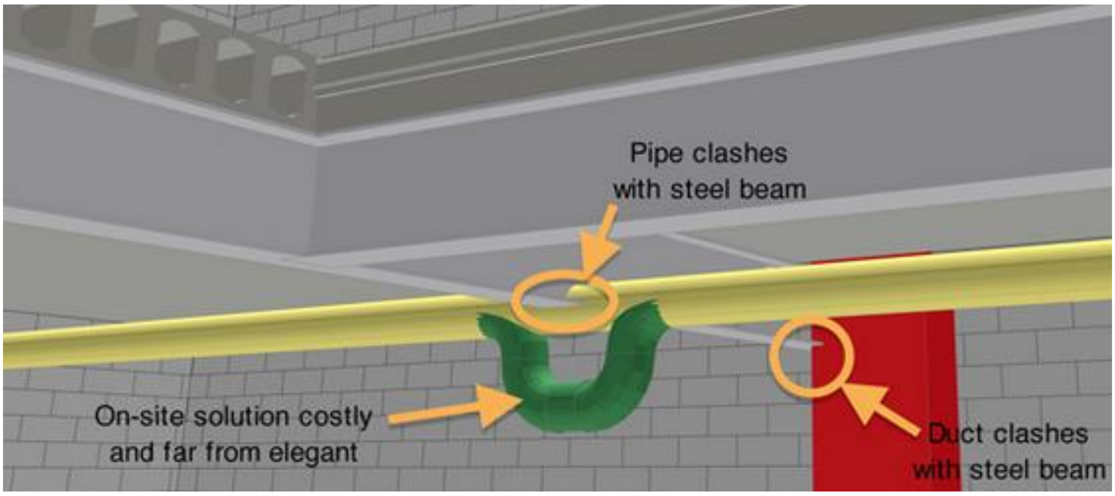


Figure 8: Illustration of clash detection. Source: BDE (2014).

2.5.3 Surveying and machine guidance

Data from surveying has since the middle of the 1980s been handled in x, y, and z coordinates (Tyréns, 2012). The coordinates are used to create terrain models in order to generate level curves or volume calculations. But when the information is handed over to production it has been in the form of paper drawings. For the surveyor this means a lot of manual converting and calculations of surveying data, and time consuming work with marking up where to excavate or fill in order to guide the machine operator (Tyréns, 2012). When working with BIM, models can be loaded into the excavator's computer and guide the machine with the help of GPS.

Figure 9: Illustration of model-based machine guidance. Source: Tyréns (2012).

2.5.4 Model-based quantity take-off

Quantity calculations have for a long time been conducted manually from 2D drawings (Jongeling, 2008). This is both time consuming, expensive and connected to high risk regarding incorrect quantity estimations (Fransson, 2012). With the help of BIM, material quantities can automatically be extracted from the model and included in cost estimations or schedules (Azhar, 2012).

There are several ways to make quantity take-offs based on a model. Following methods are some of the most common available today (Viklund, 2011). Firstly, it is possible to use quantity functions built into the BIM software in order to create lists of quantities (Viklund, 2011). The lists can then be exported into the most common cost estimation software. An advantage of this method is that it is possible to decide what information that is to be presented in the bills of quantities (Viklund, 2011). Some disadvantages on the other hand are that many BIM software can be complicated to use for people with less computer experience and that software licences are very expensive (Viklund, 2011). Furthermore, it is very important to specify which software every designer can use since the estimator and scheduler need to have access to the same software.

Another method is to use external third party software, such as Vico Software or Tocoman iLink, to extract information from the models and connect it to cost estimations and time schedules. (Viklund, 2011). This is illustrated in Figure 10. An advantage of this method is that the external software often is user friendly and can be used by people without 3D modelling experience. The software is sufficient for cost estimations and scheduling, but other information that can be useful for different purposes will need to be handled by other methods (Viklund, 2011). It is also important that there is a defined system for coding the objects in order to in a safe way extract the information without mistakes.

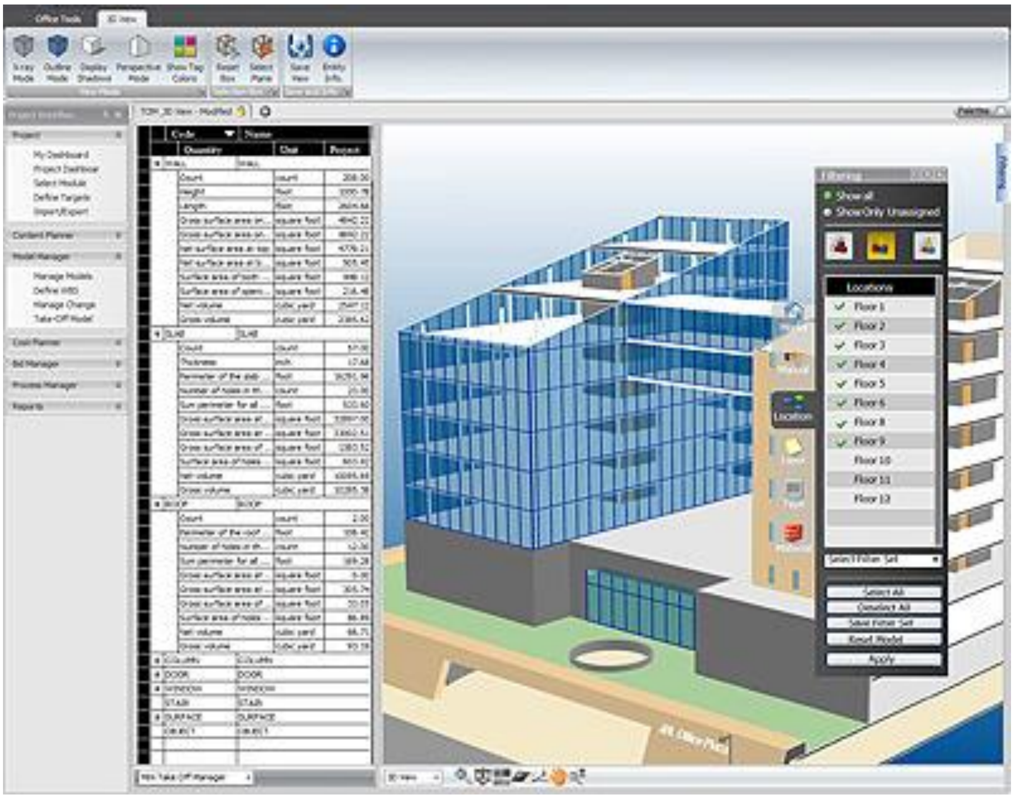


Figure 10: Illustration of quantities connected to a model. Source: Vicosoftware (2014).

If combining multiple models or doing the quantity take-off in other software than that in which the model was created, a third alternative is to use the open IFC file format that most BIM software today can handle (Viklund, 2011). But since the format is still not fully developed there are often deficiencies, such as changed geometries, when exporting and importing models.

2.5.5 Model-based scheduling

Traditional scheduling methods show dependencies between activities but they do not connect the tree dimensions of space with aspects of time (Staub-French and Khanzode, 2007). However, information of space and time is closely related and important for planning, evaluation, monitoring, and coordination of the construction process. Visualizing the construction process through traditional scheduling is not effective, leading to differing views on how the work will be conducted at site (Staub-French and Khanzode, 2007). This results in a reactive project management where problems are detected and resolved during construction. In order to create a proactive management it is important for project teams to visualize the construction process in four dimensions (Staub-French and Khanzode, 2007). Creating this link between space and time is one of the visions with BIM and referred to as the fourth dimension of CAD. The main idea is to connect activities in the time plan to objects in the 3D model (Nilsson and Mårtensson, 2009), enabling visual simulations of the building process by hiding and revealing objects in a sequential order (Lindström, 2013). The visualized 4D models can help managers make decisions about different method alternatives (Nilsson and Mårtensson, 2009), and since every object can be coded with information such as size, material, required workforce and equipment, they can be used to make time plans, material delivery plans, purchasing schedules, etc. (Bengtsson and Jauernig, 2008). In big projects with many actors it can also be possible to connect different models and optimize production together with other actors (Bengtsson and Jauernig, 2008).

2.5.6 Model-based cost estimating

To connect cost estimations to a model is referred to as the fifth dimension of CAD. The vision is that quantities from the model should be connected to a cost database, which then automatically would generate cost calculations (Bengtsson and Jauernig, 2008). The model should also be dynamic, meaning that when changes are made in the model or the cost database, the cost estimations will change as well (Lindström, 2013). A major opportunity of this system is that different design options can be compared and then act as a supporting base for decision-making. Furthermore, when connected to time aspects the model can facilitate cost control in real time, giving managers the opportunity to monitor cost developments during projects (Lindström, 2013).

2.6 Implementation issues and the need for standardization

Many and different stakeholders in building and construction projects lead to difficulties for effective and efficient collaboration. Together with the fact that construction takes place in projects creates challenges both for transferring knowledge among projects and to the permanent organization (Linderoth, 2009). This implies that the benefits of BIM technology are achieved in temporary coalitions of actors in projects, which creates a challenge for the permanent organization to transfer and routinize benefits from one project to another.

Today BIM is a very hot subject and frequently mentioned in different construction-related journals and other literature. One of the main issues discussed related to the implementation of BIM is the need for standardization. There are several well-established organizations and authorities, but also relatively new actors, in Sweden that have great interest in the implementation of BIM (Ekholm et al, 2013). Trafikverket is one of them and in their report ”Öppen BIM-standard” they explain that there is a need to standardize informational systems to enable as efficient informational exchange as possible. They elaborate by saying that since misunderstandings can increase costs and waste time, it is necessary to have common terminology and concepts in order for actors in the industry to understand each other. Azhar et al (2012) present similar arguments and say that the integration of technological applications and collaboration between different teams implies that multiple users may need access to the same model. This will require protocols and procedures to ensure that the information put into the model is understandable to all participants, which further implies that BIM standards are necessary. This opinion is also supported in the report *”BIM- the need for standardization”* financed by SBUF (Swedish Construction Industry’s Development Fund). It concludes that it is essential to develop BIM standards and clarify roles and responsibilities among actors, and that the industry actively participate in this process. Ekholm et al (2013) also emphasize the need for standardization and argue that for BIM to be successful, common national and international standards must be established as well as guidelines for the implementation of BIM.

2.6.1 Interoperability between different software

Azhar et al. (2012) describes interoperability as the ability of different software systems to exchange data information. The main reason to improve interoperability in the construction industry is to enhance the cooperation between different actors, by standardizing file formats between various applications. Insufficient interoperability costs money and is time consuming to resolve (Man, 2007). By creating standards of file formats the ability to use, move, change, and exchange information between different applications is enabled.

Advancements in this area have been made but there still are a lot of difficulties due to the lack of developed tools and standards (Azhar et al, 2012). The development of industry foundation classes (IFC) and XML schemas has eased the difficulties with interoperability, but these standards are insufficient and more comprehensive standards need to be established (Azhar et al, 2012).

According to BIM Alliance (2014), standards concerning IT are divided into three parts; definition of concepts, data models, and processes. Common concepts and classification of concepts is needed for understanding each other, neutral data formats is necessary to enable the exchange of data information between actors and uniform processes will ensure accurate exchange of data and common practices (BIM Alliance, 2014). Here, a neutral data formats will be described to illustrate some of the challenges the industry faces today and classification systems will be presented.

IFC

Industry Foundation Classes (IFC) is an international open standard for coordination of information. It is developed by the organization buildingSMART who specializes in interoperability and is founded to overcome problems that occur when information exchange between software is made. The goal is that all development of software in the industry should be in accordance to the rules that are established in the IFC-framework (buildingSMART, 2014). Furthermore, IFC is in accordance to the standardized mapping of terms, the so called “International Framework for Dictionaries” (IFD), which should be considered a framework for determining concepts (Trafikverket, 2013). On a practical level this standardization would mean that the exchange of data between software such as CAD, cost estimations and time planning should be transferred without manual intervention, see Figure 11 (buildingSMART, 2014).

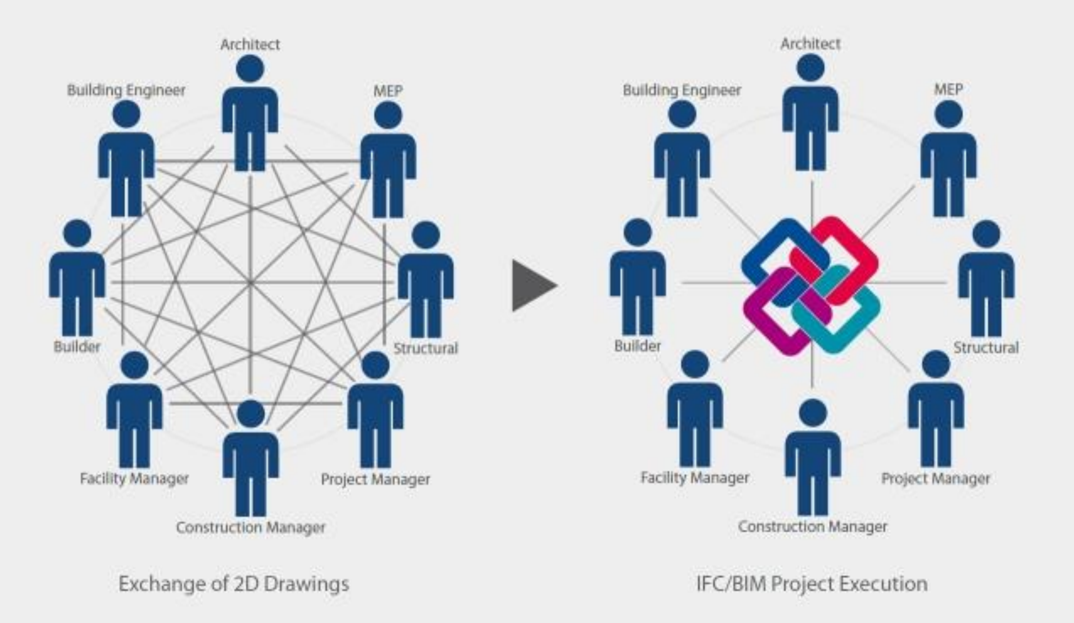


Figure 11: A comparison of information sharing as it is done today and the vision when using IFC and implementing BIM processes. Source: buildingSMART, 2014.

However, there are some compatibility issues with IFC. No attempts to use IFC have been fully satisfying as some data is lost when transferring information from one program to another (Trafikverket, 2013). This is because of the systems flexibility, which will make one program understand the information in a different way than another program. This requires time consuming and somewhat complicated manual controls after the export is done to make sure that the data is accurate. Additionally, the handling of databases becomes slow when information is stored and the loading of IFC-files into CAD-programs is very slow (Trafikverket, 2013).

Today the IFC computer model mostly concerns design and production of houses and installations, some maintenance and does not consider specific needs of civil engineering (Trafikverket, 2013). Furthermore, it is limited when it comes to handling geographical information, such as land use and natural conditions.

LandXML

LandXML is an open specification standard for the exchange of civil engineering and terrain data and was originally developed by LandXML.org, driven by a consortium of partners (LandXML, 2014). The purpose of the standard is to transfer engineering design data between producers and customers, to provide a data format suitable for long-term archival and to provide a standard format for electronic design submission (LandXML, 2014). LandXML has the intention of being equivalent to IFC for civil engineering projects (Trafikverket, 2013). However, it is not yet extensive enough nor is it compatible with IFC.

LandXML consists of data such as for example map data, plot data, 3D road-, street- and railway models, as well as waterways and pipe networks (Ekholm et al, 2013). Furthermore, the LandXML scheme covers basic information that is needed for ground exploitation and it has been implemented in larger software. Unfortunately, the development of this system is at a halt at the moment due to lack of interest by developers. However, both Open Geospatial Consortium and buildingSMART are actors who want to take over the development of LandXML (Ekholm et al, 2013). buildingSMART see the format being of use in the future, first as a compatible format connected to the IFC and eventually as a standard that is integrated in IFC (Trafikverket, 2013).

2.6.2 Classification systems

A classification system is a collection of information that explains how to classify for example a building, how to organize information about the building according to the structural relationship between elements. During construction projects there is a massive exchange of data and information between different actors. It can be information used only once or information that is relevant during the whole project lifecycle. To enable an efficient exchange of data it is vital that the actors talk the same language, meaning that they should use the same concepts and codes (Svensk Byggtjänst, 2013). Trafikverket (2013) also support this by saying that a common computer format and a common language is important in order to be able to exchange data and to specify the data so it is understandable for the receiver. Furthermore, a computer integrated process puts additional pressure on likewise structured information about the related building environment (Svensk Byggtjänst, 2013).

One of the largest problems with the implementation of BIM is the lack of industry standards for coding objects. In Sweden there are no regulations of how to code objects, but this is decided in each project respectively. That client and authorities specifies requirements could be a necessary driving force in the implementation of BIM (Trafikverket, 2013). However, there are guidelines that are common to use. Two Swedish classification systems are Bygghandlingar 90 (BH90) and BSAB 96. BH90 constitute the building sectors guidelines for the design of integrated and efficient construction documents. BSAB 96 is a classification system intended to organize information along with the building process (Svensk Byggtjänst, 2013).

Bygghandlingar 90

In civil engineering projects, digital information in different CAD-programs is used and to get an effective use of these there need to be rules for how to code information in the models. These rules have to be agreed and followed by all actors. There is an international standard for determining layers in CAD-programs called SSISO 13567. However, object coding is referred to national rules and guidelines (Eckerberg, 2011).

BH90 is issued by the Swedish Standard Institute (SIS) and is a publication with eight parts containing recommendations to the building sector of how construction documents should be designed to be consistent and useful. Part seven, called *"Classification of civil engineering"* contains guidelines for how to present digital civil engineering models, landscapes and civil engineering information. Additionally, it describes how to classify and codify objects (Eckerberg et al, 2011). However, the guidelines have not yet been recognized in the software used by schedulers and designers (Ekholm et al, 2013).

BSAB 96

BSAB 96 is owned and maintained by Svensk byggtjänst and is a system for a common structure of information in construction and civil engineering projects (Svensk Byggtjänst, 2014). It is a language developed for the construction sector in order to facilitate efficient communication and informational flows. The system is based in the SS-ISO 12006-2 (Organization of information about construction works - Part 2: Framework for classification of information) and should be used to classify constructions and its parts (Svensk Byggtjänst, 2014). Furthermore, BSAB 96 is a system based on hierarchical structured tables with an increasing level of detail, definitions and codes. It is also used to develop AMA the Swedish construction sectors common regulations for material and work descriptions (Svensk Byggtjänst, 2014).

The tables in BSAB 96 is based on several views; infrastructural entity, construction, type of space, building part, production result, and resources (Figure 12) (Svensk Byggtjänst, 2014).

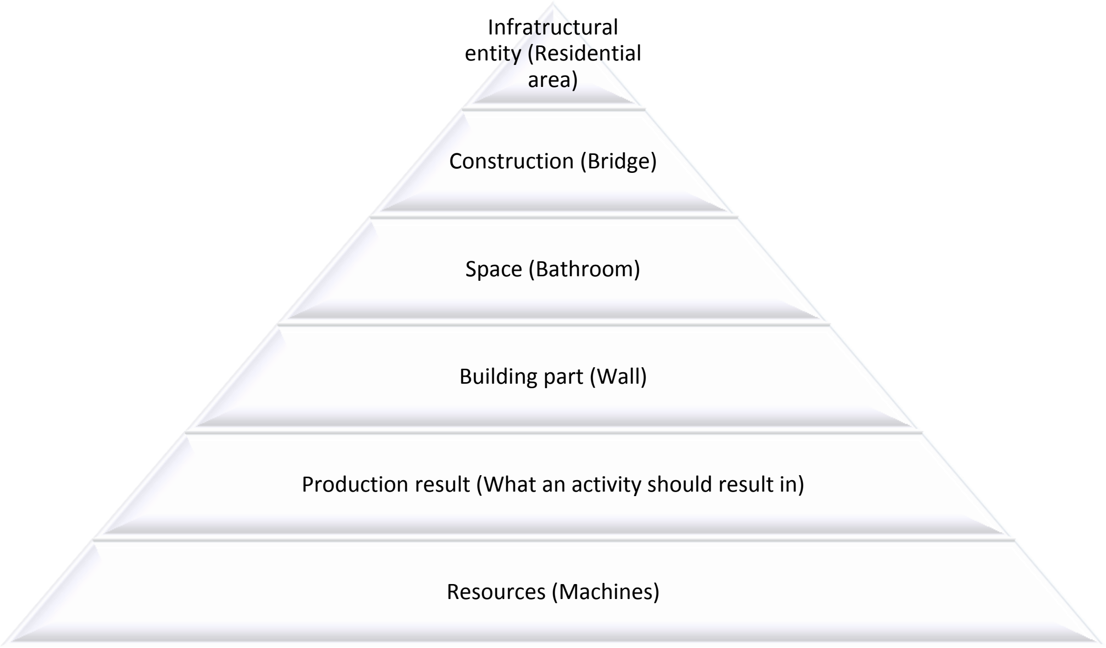


Figure 12: The base for which the tables in BSAB are defined. Source: Svensk Byggtjänst, 2014.

The BSAB 96 system works in theory, but in practice there are some major difficulties that need to be recognized (Svensk Byggtjänst, 2014). One problem is that people in general do not have the right understanding of how BSAB 96 is structured and how to apply it on their projects. Furthermore, it is hard to find codes for what ordinary people perceive as "building parts". This is because the table for building parts is based on function rather than construction, which is a common misunderstanding. A certain type of outer wall does not have a specific code, but several codes based on its three functions; outer climate shield, inner climate shield and facade. The definitions of how to use the codes are also incomplete which can lead to different interpretations by different people (Svensk Byggtjänst, 2014).

Another problem is that all the tables are not used today due to a lack of interest, which consequently has led to that some tables are not comprehensive enough and some tables are missing (Svensk Byggtjänst, 2014). Today, only the tables for building parts and the table for production results are used. The use of BIM has led to high demand for the missing tables and codes and therefore the industry has developed other ways to classify resources. Some examples are BK04 codes developed by suppliers, RSK numbers developed by the HVAC sector, and EIO developed in the electricity sector (Svensk Byggtjänst, 2014).

2.6.3 Legal

Highlighting the legal issues in the adoption of BIM will ensure that the industry can collaborate without the worry of adverse legal consequences (Udom, 2012). This has created a discussion around legal issues such as data ownership, risk sharing, and proprietary issues. Among the stakeholders, questions such as who should develop and operate building information and how developmental and operational costs should be distributed are raised. Unfortunately, there has been little progress in the development of model BIM contract documents (Azhar, 2012). If BIM is used internally for a project, where members of the same firm/consortium work together; this would not require changes to contract and simple common standards would suffice. However, for BIM involving the collaboration of consultants, fabrication modellers, specialist manufacturers, contractors, sub contractors and facility mangers the construction contracts in use at present would require amendments to cover the legal issues that may arise (Udom, 2012).

One legal issue is the number of models to be created, their relationship, and the relationship between the model(s) and 2D drawings. Where multiple models are used, the parties should indicate which model takes priority in the event of conflict in the information contained in each of the models. The parties would need to agree on the content and format of each model and the required standards to be employed; these may be set out in a BIM execution plan that would form part of the contract documents. Today, for example the technical description legally outweighs drawings. It is not yet decided whether the information in the model should be of equally great importance or even of greater importance than 2D drawings. Svensk Byggtjänst (2013) has suggested a BIM process were a database acts as the original information and documents extracted from it has a lower legal status. This database could contain an informational model which than would have a higher legal status than for example a drawing. This suggestion would imply an extensive change and will probably take some time to implement (Svensk Byggtjänst, 2013).

2.7 Interaction between human and technology

Research demonstrates that implementation of Information and Communication Technology (ICT) systems, such as BIM, into an organization often result in a change of direction from the initially intended plan. This is because of the interaction between technology and the industries complex nature where learning and knowledge development has a critical role regarding the adoption and use of the technology. This complex nature is constructed by e.g. norms, actors' frames of references, industry characteristics, rules and regulation, and company culture (Linderoth, 2009). The implementation will also be affected by the features of the ICT, which is the technology designers' assumptions about the context for use and future users' roles, relationships, and competencies (Linderoth, 2009). This means that the use and adoption of BIM will be shaped by the interplay between the technology's features and the context in which it would be adopted and used (Linderoth, 2009).

When the use of computers increased so did the amount of research looking at the interaction between humans and computers (Gustafsson, 2006). There are three requirements that need to be satisfied in order for a technology to be successful:

- The product has to be able to perform what it was design to do
- The product should be easy to use
- People should want to use the product (Gustafsson, 2006)

In a questionnaire survey investigating the benefits and barriers of BIM Yan and Damian (2008) conclude that the biggest barrier for the implementation of BIM is that companies believe that training will cost too much in time and human resources. Furthermore they found that social and habitual resistance to change also is a major difficulty in the adoption of BIM. One of the reasons that BIM projects fail is that there are differing expectations and goals for the end product. To enable common expectations and goals, these need to be defined in an early stage of the project in collaboration between all involved actors. Joint goal documents and agreements, such as e.g. partnering contracts, are one way to support common strategies.

3 Method

In this Master's Thesis a qualitative research approach has been used with the aim to gain a profound understanding of difficulties in the interaction between humans and technology. The qualitative research method is distinguished from the quantitative research method in literature. In qualitative methods low structured data is researched, such as information gained in interviews or surveys as oppose to quantitative methods were instead highly structured data, were statistic- or mathematical methods are used as the base for information (Thurén, 2007). Qualitative research aims to expand the understanding for attitudes and ideas that result in a certain human behaviour rather than to map what people do and say. The focus lies in the consideration of the *why* rather than the *what*. One of the strength of a qualitative study is that knowledge gained in the process could give insights that change the course of the thesis (Savin-Baden and Major, 2013). Furthermore, while conducting this master thesis the authors have been present at the analysed company and studied a reference project by conducting interviews with people involved. The interviews, together with researched literature, represent the base for the analysis where no generalization is made, but hypothesis is discussed and should be considered for future research.

3.1 Literature study

To gain a thorough understanding of information handling in Swedish civil engineering projects a literature study was conducted in the beginning of the Master's Thesis project. In search of literature scientific articles, books, and reports from companies and organizations in the construction industry have been reviewed. Furthermore, older Master's Theses are studied to attain a broader knowledge of what research has been conducted in the studied and related fields. The studied literature is largely originating from Sweden in order to capture the Swedish perspective, especially when studying the building process and implementation issues related to legal aspects, classification system, and development of industry standards.

3.2 Interview study

The conducted interviews have been semi-structured to enable an open discussion around the interview questions. Furthermore, to attain an understanding of the process, the interviews have been conducted in a deliberate sequence, from structural engineering, on to cost estimations and monitoring, and finally project scheduling. This was followed by additional interviews to investigate the relationship further. After each interview, the obtained information was summarized and analysed to act as a base for the results. The interviews were recorded to act as memory help.

3.3 Company presentation of Skanska

Skanska is a Swedish construction company with operations in USA, Latin America, and several European countries. The company has 10500 employees in Sweden and 55600 globally. In 2012, the global turnover was 132 billion SEK, with 30,5 billion originating from Sweden. This makes Skanska one of the largest construction companies on the Swedish market, but also world-wide (Skanska, 2014).

On the Swedish market Skanska's operations are divided into four branches:

- Construction activities
- Residential development
- Commercial property development

- Infrastructure development

Furthermore Skanska is divided into a number of regions and support functions (Skanska, 2014).

3.4 Reference project South Marieholm Bridge

The Marieholm Connection Project includes the Marieholm Tunnel, South Marieholm Bridge, and the finished Partihallsförbindelsen. The new tunnel and bridge will improve communication between Gothenburg harbour, the industries on Hisingen Island, and the central parts of Gothenburg (Trafikverket, 2014).

The South Marieholm Bridge, which is the project studied in this thesis, will be a railway bridge over Göta Älv and Säveån meant to reduce interference and increase robustness in the whole railway system and enable more rail freight. The existing Marieholm Bridge has only one track carrying all traffic into the harbour, which means that disruptions in the traffic flow are of great harm to the port activities and industry. A new complementing bridge is therefore important to increase the stability of the system (Trafikverket, 2014).

The new bridge will be built with the same principle as the existing Marieholm Bridge, that is, as an openable lift-swing bridge. As the name implies, the bridge will be located south of the existing bridge, as close as possible due to engineering aspects (Figure 13). The openable part will be 72 meters long and located seven meters above water. In total the new bridge will span 1,5 km, crossing Göta Älv River and stretching across Säveån River and the industrial areas of Marieholm and Tingstad. In addition to a rail track the bridge will also include a walk and cycle path (Trafikverket, 2014).

Figure 13: Visualization of South Marieholm Bridge next to the existing Marieholm Bridge. Source: trafikverket.se.

The construction will be performed by Skanska Sweden and the Danish contractor MT Höjgaard as a joint venture project. The contract is worth a total of SEK 791 million, of which Skanska's share is 70 percent, which amounts to 554 million (Skanska, 2014). The construction is expected to be in progress from the beginning of 2014 until the beginning of 2017 (Trafikverket, 2014). When this Master’s Thesis was conducted South Marieholm Bridge was in the middle of the design stage, but some parts of the production had started as well (Nordberg, 2014).

3.5 Presentation of interviewees

- Helén Broo, Structural engineer, Skanska Teknik.

- Christer Nordberg, Assistant project manager, South Marieholm Bridge.
- Kjell Isacsson, Scheduler, South Marieholm Bridge.
- Mats Nordell, CAD Manager civil, Skanska Teknik.
- Henrik Ljungberg, CAD Manager civil, Skanska Teknik.

3.6 Limitations

As mentioned a case study has been conducted at Skanska were interviews with solely Skanska employees has been made. We have focused on this one case, South Marieholm Bridge, which is a civil project situated in Sweden. Because of this, no general conclusion can be drawn, but the findings should only act as indications.

4 Results

In this chapter the results gained from interviews are presented. It describes the tender process at Skanska as this is the part where most of the design work is defined and structured. Furthermore, this process will be reviewed from the perspective of the designers, cost estimator and scheduler. The relation between the disciplines is presented as well as the use of BIM processes in the reference project. The strategy and difficulties for implementing BIM processes is explained based on the information gathered from the interviews.

4.1 Tender process in South Marieholm Bridge

Before a tender process begins, the market is monitored in order to evaluate possible future projects (Nordberg, 2014). This monitoring is conducted to assess if the organisation has the capacity to undertake specific future projects, but also to evaluate if the projects are in accordance with the company strategy and can lead to profits. If it is decided to prioritise a certain project, a tender organisation is established containing people who will work in the project, such as project managers, calculators, schedulers, design engineers, construction managers, etc. Figure illustrates some of the main actors in the tendering process from the reference company's point of view.

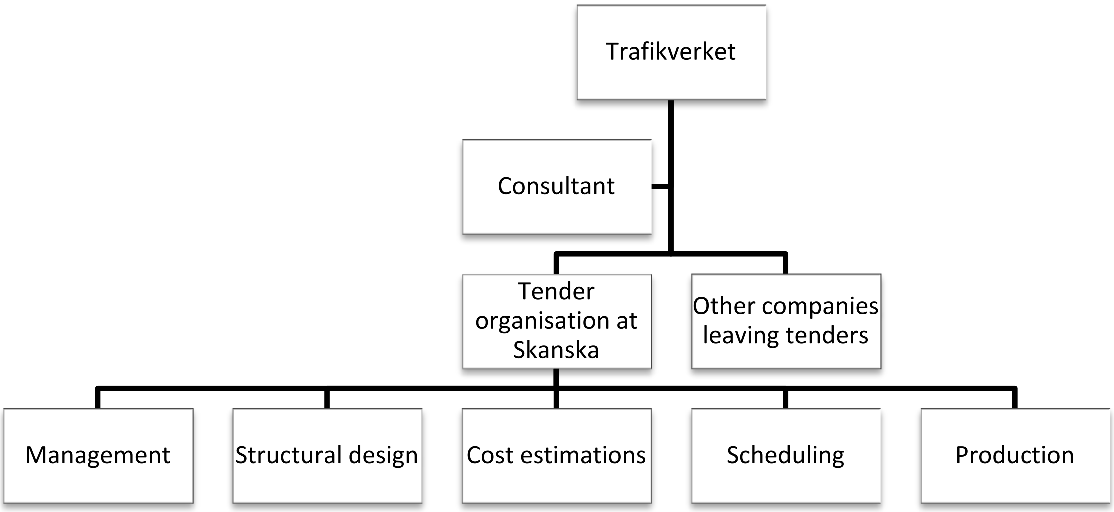


Figure 8: Main actors in the tender process from the reference company's point of view.

When the client sends out the request for tender, the tendering documents are reviewed, risk assessments are made, and responsibilities are distributed (Nordberg, 2014). An overview of the tender process is shown in Figure 9. At South Marieholm Bridge, hereinafter referred to as SMB, the project delivery method is based on a Design-Bid-Build construction contract with structural responsibility. This means that the client Trafikverket (The Swedish Transport Administration) developed a rough preliminary design with the help of a consultant before the request for tender was sent out, but that the contractor is responsible for the detailed design (Broo, 2014). This preliminary design, together with technical descriptions, geographical and topographical information was then included in the tender documents in order to guide the tender design.

During the tender process, the different disciplines within the organisation worked parallel to each other but with different phases of intensity (Nordberg, 2014). The first intense task was for Skanska Teknik, a support function with technical consultants within Skanska, to produce a design proposal based on the material delivered in the request for tender. From this, quantity information was calculated and sent to the cost estimator and the scheduler. They were then responsible for estimating costs and creating a main schedule to be included in the tender. When all the estimations were completed, a meeting was held in order to finalize the tender, set a price and send the tender to Trafikverket (Nordberg, 2014).

After Trafikverket had reviewed the different tenders and awarded Skanska with the project, the design process started immediately (Nordberg, 2014). Broo (2014) further point out that in order to have enough time, they started the design work even before they knew if they would get the project. Moreover, since there was not enough time to wait for finished design documents, the scheduling and cost estimations had to be initiated at once as well (Nordberg, 2014). Nordberg (2014) explains this by pointing out that there were no major changes to the design at this stage. Even the production started right away in terms of preparations in order to have the right resources at the right place in the right time (Nordberg, 2014). When the design, estimations, and main schedule were completed it was handed over to the production for further planning.

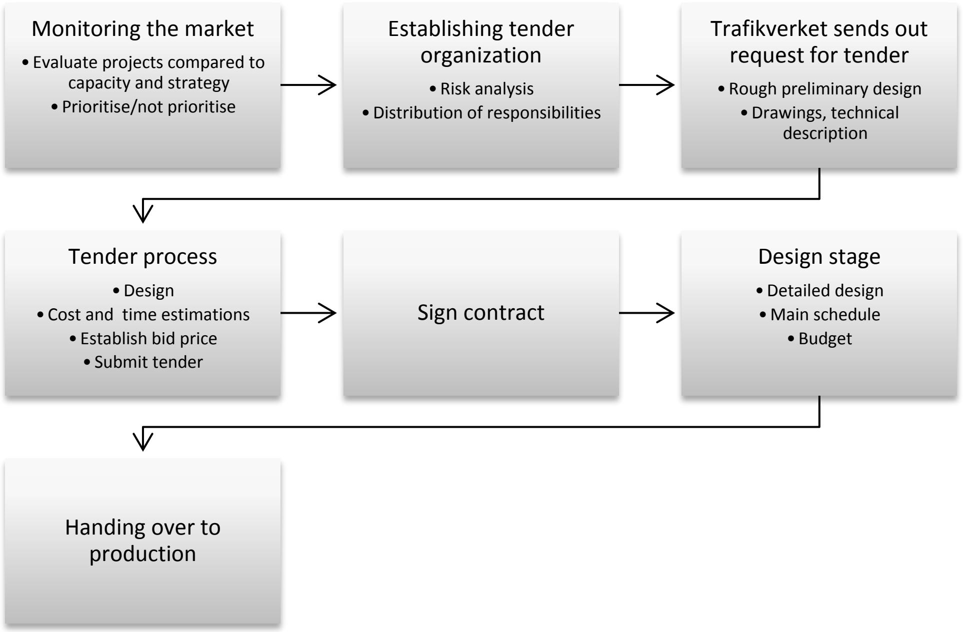


Figure 9: An overview of the tender process.

4.1.1 Coordination and information sharing

To coordinate information between disciplines at SMB there are several forms of information sharing (Nordberg, 2014). For starters, meetings are held continuously, both technical and cost estimating meetings. The tendering organisation at Skanska had meetings every week to deal with issues that arose during the tendering process (Broo, 2014).

Project information, such as drawings or technical descriptions is spread within the project through a project network (Nordberg, 2014). This network is a web-based solution to where all the project participants are connected. However, Nordberg (2014) says that if there is a change it is difficult to know if persons affected by the change have taken part of information shared within the network.

Another way to share information generated within the project is by email. However, according to Nordberg (2014), it is difficult to know if the receiver has noticed the information as no affirmation of this is given to the sender. Furthermore, how to manage email conversations is very individual when it comes to choosing subject lines and receivers.

As explained earlier, the cost estimations and scheduling are largely based on information delivered from Skanska Teknik. In connection to this, Broo (2014) says that the engineers at Skanska Teknik do not have any relation to project costs or time. Furthermore, she explains that the cost estimators seem satisfied with how the delivered information is structured, but that it can be changed if another structure would be more preferable.

Nordberg (2014) further explain that the handover from cost estimation to production could be improved. Today there is not enough time to structure and sort all documents in a preferable way. He also point out that there is a potential for improvements regarding systems for document handling and that platforms and sharepoint solutions can be of use. For example, it is possible to get updates when something is changed or added to specific folders (Nordberg, 2014). The problem with these solutions is that the knowledge of how to use them and the habit to explore them is missing.

4.1.2 Design

In SMB, Skanska Teknik was, as mentioned, responsible for estimating quantities concerning building parts, materials, surfaces, and volumes to be included in the tender proposal (Broo, 2014). Within Skanska Teknik there are two categories of designers; structural designers that calculate the structural systems and CAD designers that design models and drawings. Furthermore, some of the CAD designers have developed into BIM specialists, specialist in handling 3D models (Ljungberg, 2014). The information the structural engineers at Skanska Teknik needs in order to perform their tasks and the information they produce is illustrated in Figure 14 and will be described in the following paragraphs.

The quantity estimations were done by, among other things, performing load calculations, which resulted in dimensions for a rough structural bridge design (Broo, 2014). The basis for the proposal design consisted of documents provided by the client Trafikverket, such as drawings, a technical description of the bridge, and topographic and geographic information (Broo, 2014). As mentioned earlier Trafikverket hired a consultant to perform the preliminary design that was included in the tender documents before sending out the request for tender. Furthermore, measurements that are specified in these documents are fixed and have to be followed (Broo, 2014). An example of fixed measurements in this project was minimum height between the water and the bottom of the bridge. Where there are no specified measurements Skanska Teknik can choose the dimensions they find most suitable (Broo, 2014).

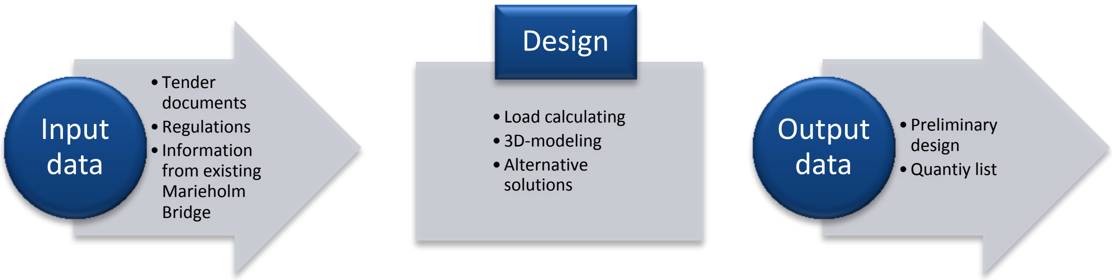
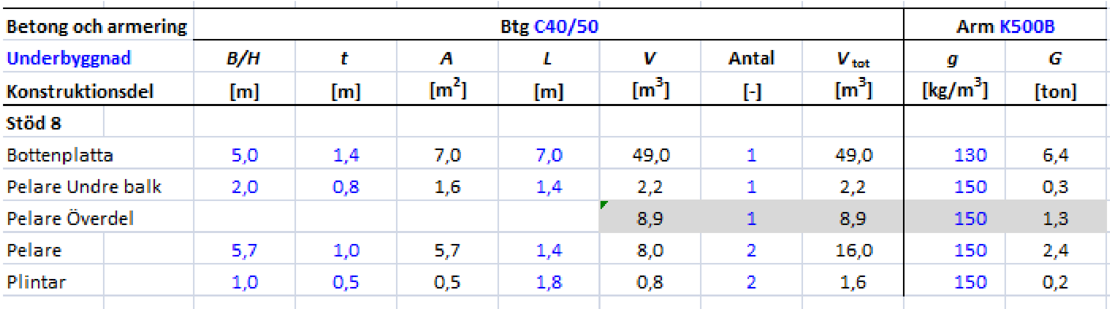


Figure 14: The information input and output in the tendering stage from Skanska Teknik's perspective.

Skanska Teknik made a preliminary design based on the documents provided by Trafikverket in order to calculate quantities of e.g. concrete, concrete casts, rebar, but also various details such as railings (Broo, 2014). The information that is delivered from Skanska Teknik is a quantity list in Excel format. Figure 10 is a cutout of column 8 from the quantity list delivered by Skanska Teknik. It is coded by location (stöd 8) and building part (Bottenplatta, pelare under balk etc.). In addition to the tender documents, Skanska Teknik also need to adhere to Trafikverket's general demands and advises as well as regulations such as Eurocode (Broo, 2014). Moreover, SMB will be very similar to the existing Marieholm Bridge, which Skanska designed and built as well. Because of this, there was much information available and used as support.



Betong och armering	Btg C40/50							Arm K500B	
Underbyggnad	*B/H*	*t*	*A*	*L*	*V*	Antal	V_{tot}	*g*	*G*
Konstruktionsdel	[m]	[m]	[m^2]	[m]	[m^3]	[-]	[m^3]	[kg/m^3]	[ton]
Stöd 8									
Bottenplatta	5,0	1,4	7,0	7,0	49,0	1	49,0	130	6,4
Pelare Undre balk	2,0	0,8	1,6	1,4	2,2	1	2,2	150	0,3
Pelare Överdel					8,9	1	8,9	150	1,3
Pelare	5,7	1,0	5,7	1,4	8,0	2	16,0	150	2,4
Plintar	1,0	0,5	0,5	1,8	0,8	2	1,6	150	0,2

Figure 15: Cutout from the quantity list delivered by Skanska Teknik. It shows the location and building part concerning column 8.

Skanska Teknik also proposes alternative solutions that differ from the given drawings in order to eventually present more beneficial choices (Broo, 2014). These different alternatives were discussed together with the rest of the tendering organisation on a regular basis. When dimensions of a construction are calculated, the quantities are obtained by measuring the drawings (Broo, 2014). Furthermore, some columns were parametrically 3D modelled, enabling the model to be used for all the columns. The modelling in the tender stage was used for visualization. However, Helen says that it is unclear whether this will be faster compared to a traditional design process (Broo, 2014).

4.1.3 Cost estimation

The information used to make the cost estimations is the tender documents given by Trafikverket, quantities calculated by Skanska Teknik, and information from time planning (Nordberg, 2014). The information needed for cost estimating and the information produced by the cost estimators is shown in Figure 16 and will be further described in the following paragraphs.

The structure for cost estimations is set early on in the tendering process (Nordberg, 2014). Furthermore, the structure is defined and broken down preferably to fit the project. If this structure is given from the start or defined by Skanska depends on the project delivery method (Nordberg, 2014). In a Design-Bid-Build project, quantities are often delivered from the client and therefore have a given structure. In projects delivered through Design-Build contracts, quantification is made as a part of the structural design stage, hence, Skanska defines the structure. However, in SMB the contractual form is, as mentioned, Design-Bid-Build with structural responsibility, therefore Skanska is responsible for the structure (Nordberg, 2014).

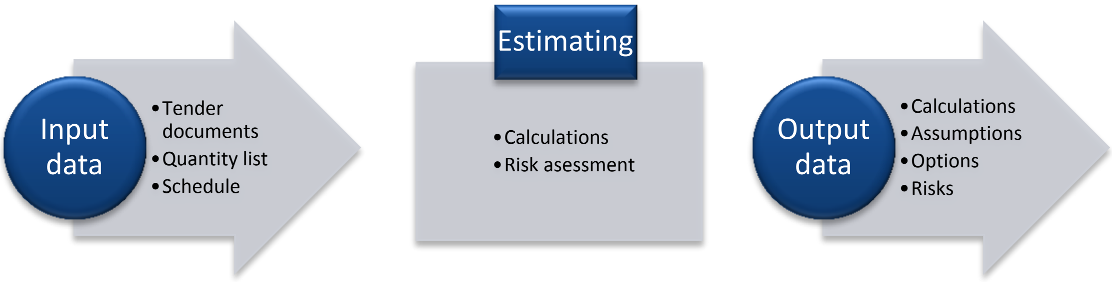


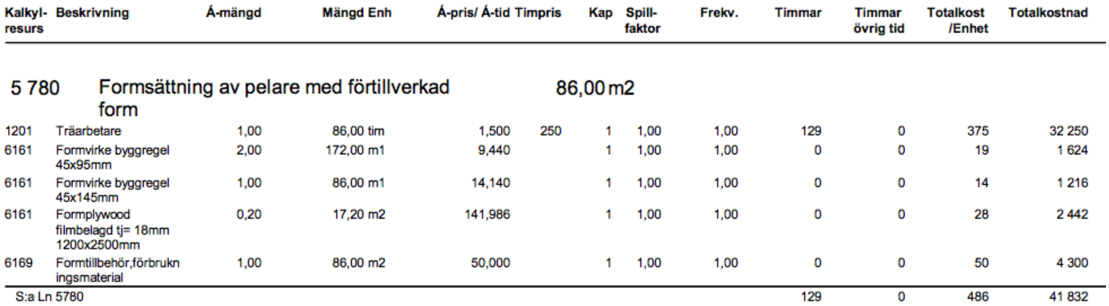
Figure 16: The information input and output in the tendering stage from the estimator's perspective.

After receiving the list of quantification, direct costs are estimated. Direct costs are costs related to actions you need to do at the worksite, e.g. costs for materials or equipment (Nordberg, 2014). If the estimators consider any information about quantities to be wrong or has potential of improvements, a dialog is started with the structural engineer. Often quantities are changed several times during the tender phase (Nordberg, 2014). In addition to the dependency of Skanska Teknik, the cost estimator also is dependent of information from the schedule. This is because general costs, such as costs for insurance, can be established first when the time planning is done as it is time dependent (Nordberg, 2014).

The cost estimations made in the tender should be as accurate and neutral as possible with all conditions considered (Nordberg, 2014). This means that costs should not be set too high in order to create large margins, nor too low in order to leave the lowest bid. Costs for risks and cost reductions for opportunities are calculated on the side.

At Skanska a program called Spik is used for cost estimations. (Nordberg, 2014), explains that it is not possible to import information directly from a CAD-model into Spik. It is most often done by importing to Excel in first hand and then in to Spik. However, there is still much manual work in between depending on how the excel is structured by Skanska Teknik (Nordberg, 2014). Nordberg (2014) further explains that in SMB the information from Skanska Teknik was manually inserted to Spik.

In Spik there are finished recipes that can be used or adapted to specific building parts. The recipes are detailed information of costs connected to a certain building part or activity. New recipes can also be made if it is necessary. The recipes are based on activities, Nordberg (2014) says. Figure 17 illustrates how parts of the casting for column 8 in SMB is structured. The recipe is built up of material, tools, resources that added together creates a unit cost, in this case kr/m^2. Information required to perform the estimation is quantity information and project specific information and the result is a total cost for the specific activity.



Kalkyl-resurs	Beskrivning	Á-mängd	Mängd Enh	Á-pris/ Á-tid	Timpris	Kap	Spill-faktor	Frekv.	Timmar	Timmar övrig tid	Totalkost /Enhet	Totalkostnad
5 780	Formsättning av pelare med förtillverkad form				86,00 m2							
1201	Träarbetare	1,00	86,00 tim	1,500	250	1	1,00	1,00	129	0	375	32 250
6161	Formvirke byggregel 45x95mm	2,00	172,00 m1	9,440		1	1,00	1,00	0	0	19	1 624
6161	Formvirke byggregel 45x145mm	1,00	86,00 m1	14,140		1	1,00	1,00	0	0	14	1 216
6161	Formplywood filmbelagd tj= 18mm 1200x2500mm	0,20	17,20 m2	141,986		1	1,00	1,00	0	0	28	2 442
6169	Formtillbehör,förbrukningsmaterial	1,00	86,00 m2	50,000		1	1,00	1,00	0	0	50	4 300
S:a Ln 5780									129	0	486	41 832

Figure 17: Cutout from the cost estimation displaying information for parts of the casting for column 8. The figure only shows a very small part of the estimations.

One of the main task of the cost estimator is to start the project off with an accurate budget and to hand over this information to the production that will take over the responsibility (Nordberg, 2014). In this informative hand over, calculations, assumptions, options, and risks are presented to the production management. The information includes all documents, structured as well as unstructured. According to Nordberg (2014), the cost estimations should be considered as reasoning based on experience and not as finished recipes. Furthermore, as the actual construction starts, cost estimations are synchronized with changes that occur during the production (Nordberg, 2014).

4.1.4 Scheduling

The main schedule at SMB was created by gathering information of the project, creating activities and putting them in a logical sequence (Isacsson, 2014). Also, allocation of resources, such as staff and machines, were planned. A time schedule should as well as cost estimations be as neutral as possible with all known conditions considered (Nordberg, 2014). The information needed was the design solutions delivered by Skanska Teknik and time specifications stated in the tender documents (Isacsson, 2014). The information needed for scheduling and the information produced by the schedulers is shown in Figure 18 and will be further described in the following paragraphs.

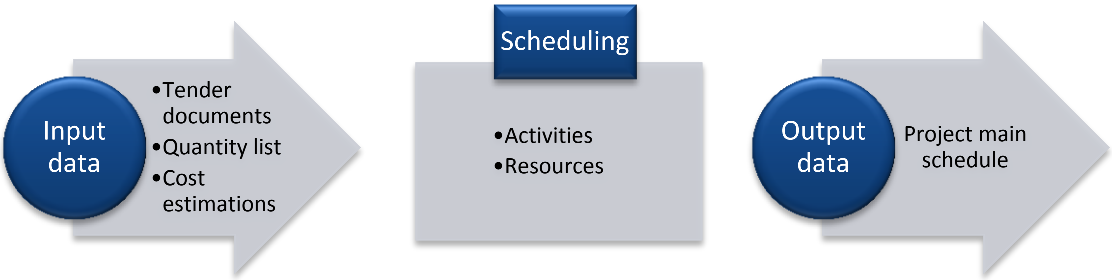
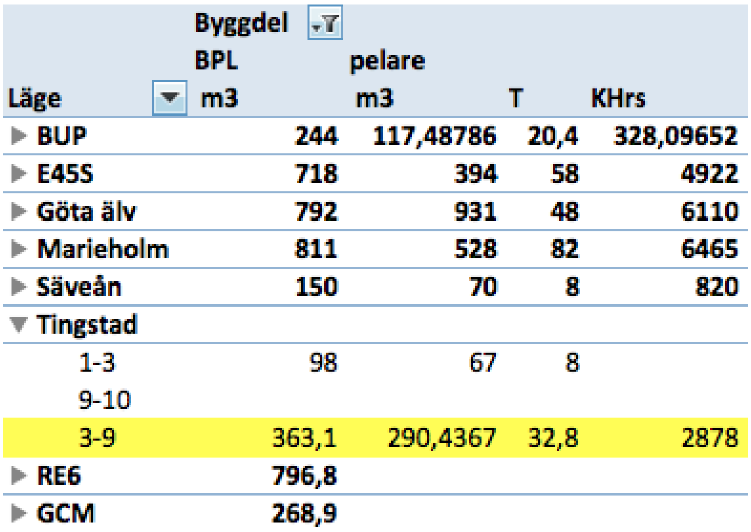


Figure 18: The information input and output in the tendering stage from the scheduler's perspective.

The project planner entered the project in an early stage and worked with the specifications of fixed times received by Trafikverket (Isacsson, 2014). Since SMB is a railway project there are scheduled downtimes in the train traffic. These times have been planned years in advance, which makes them vital to follow (Isacsson, 2014). The next step was to break down the information in activities with starting and ending points, to create a framework for the planning process.

The information provided by Skanska Teknik was, as mentioned, delivered in the form of quantity lists with volumes and weights. The data is delivered in the form of Excel sheets and Isacsson (2014) explains that much of the planning work is performed in Excel as well. This information then had to be translated in some way. Isacsson (2014) explain that he generalised the quantities, translated them into cubic meters of concrete, tons of rebar, square meters of concrete casts, etc. He then combined this information with information on how long time it will take to complete each part, e.g. hours per cubic meter of concrete. This capacity information was collected from both personal experience and comparisons to similar finished constructions. The result from this combination of time and quantities was an expected completion time per ton of concrete. In this calculation everything that is to be assembled in the concrete elements was included, that is concrete, rebar, casts, cooling coils, etc. From this he got a number that described the total expected time consumption for each concrete element. From experience he knows that this generalised process give remarkably solid numbers (Isacsson, 2014). Figure 19 illustrates how some of the scheduling data is structured. The picture illustrate how building parts are combined into groups, column 8 is include in group 3-9.



	Byggdel			
	BPL	pelare		
Läge	m3	m3	T	KHrs
▶ BUP	244	117,48786	20,4	328,09652
▶ E45S	718	394	58	4922
▶ Göta älv	792	931	48	6110
▶ Marieholm	811	528	82	6465
▶ Säveån	150	70	8	820
▼ Tingstad				
1-3	98	67	8	
9-10				
3-9	363,1	290,4367	32,8	2878
▶ RE6	796,8			
▶ GCM	268,9			

Figure 19: Cutout from scheduling data document. The picture illustrate how building parts are combined into groups, column 8 is include in 3-9.

Isacsson (2014) says that there are many ways of time scheduling but he prefers to produce generalised main schedules. He further explains that the planner who sits in the office cannot go out on site and question the workflow. According to him it is more important that the production staff feels empowered and can plan the details as they find best. The foremen on site are not expected to know the entire main schedule, but only what activities that needs to be finished next. They then figure out how to perform this in the best way and break down the main activities in smaller parts. In this process other software than Primavera is often used. Some use a software called Asta, others use paper and pen, or Excel. Furthermore Isacsson (2014) explain that Primavera and Asta are not fully compatible with each other. Information can be exchange between the softaware with manual intervention (Isacsson, 2014). Additionally, the foremen have to adapt the order of assembly depending on many unforeseen aspects, issues that are not visible from the office. That is why Isacsson (2014) only combines activities and describes when they should be finished.

When the activities were created they were also adapted to production in order to ease the assembly as much as possible. The activities were then inserted into a planning software called Primavera (Figure 20), to connect them to each other and create a logical sequential order (Isacsson, 2014). Several activities are combined into larger generalised activities.

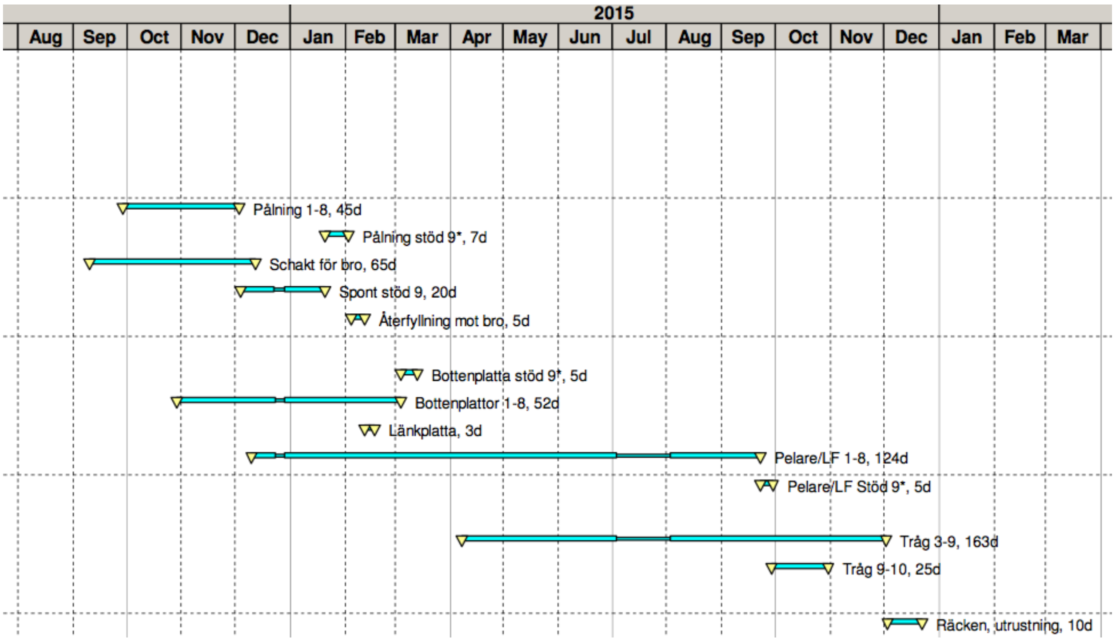


Figure 20: Cutout from the schedule illustrating the order of activities connected to column 8.

Furthermore, during the course of production, the schedule needs to be continuously monitored (Isacsson, 2014). This can be done by going out on site and check how much of the work that is completed. By using the scheduling document the progress on every activity then can be inserted. Furthermore, during the production there is a three-week continuous schedule always up to date. Also, Isacsson (2014) explains that the scheduling software is more than just planning; it also displays budgeted costs, which enables for easy cash flow analyses by distributing the costs over time.

4.1.5 Common information need for cost estimating and scheduling

Nordberg (2014) states that there is a potential for improvements in the collaboration between cost estimation and scheduling. One of the first issues hindering better coordination is that the disciplines use different software, and that information cannot be exchanged between them (Nordberg, 2014). Another problem is to find a code structure and a level of detail that is suitable for both disciplines and can be used in their respective software. The cost estimations are created in a very detailed level but do not describe in what order the different tasks will be performed, while the main purpose of the schedule is to show the work sequence (Nordberg, 2014). Furthermore, Isacsson (2014) says that cost estimation resources and scheduling resources are not the same. Nordberg (2014) explains this by saying that the schedule is dependent on time while the cost estimations are dependent on costs. Isacsson (2014) further elaborates through an example of excavations. In a cost estimation every component needs to be accounted for. That is, what the excavator costs, what trucks cost, what tipping fees cost, what craftsmen cost, etc. These costs are extracted by using called recipes where a number of cubic meters are inserted and costs for the work automatically displayed. In the schedule this detailed information is not interesting. Here the important information is the number of cubic meters, how long time this will take, and how many workers that are needed. The scheduling resource can then be called excavation (Isacsson, 2014). Furthermore, in relation to the delivered quantity information Nordberg (2014) explains that there are tasks that cannot be understood from quantities. Lets take the example of excavations again. Here it is relevant to know the quantity of the mass that is to be excavated, but it does not describe the work needed to keep the excavation dry from water, the machines needed, or the man-hours needed (Nordberg, 2014). There are also other areas where quantities are not fully connected to the cost estimations. For example, the finished schedule acts as input data for the cost estimations since the times are needed in order to calculate the general costs such as costs for renting equipment.

Nordberg (2014) says that he does not thinks that it would be very difficult to create a code structure that fits both cost estimating and scheduling software. The basic structure for both disciplines is location (where in the project geographically) and building part, but it is combined in different ways (Isacsson, 2014). Long before the cost estimations are finished, the planners need to have produced a somewhat finished main schedule in order to compare the expected times between the two. This is done in order for the cost estimation and schedule to be consistent when handed over to production (Isacsson, 2014).

4.2 BIM in South Marieholm Bridge

In South Marieholm Bridge there is a budget for 3D modelling, but how that money will be used is not yet established. The discussion of what area could benefit from a 3D-model the most is going on (Nordberg, 2014). Models are created with the purpose of using them in production, but how it will be of use is not evident yet. The idea is to verify the benefits of bringing the model to production to ease the implementation of BIM in the organization.

The focus of implementing BIM in SMB has been on visualization, surveying and machine guidance, and on using models on site (Nordell, 2014). Furthermore, models that are used as support in the production are complemented with drawings (Ljungberg, 2014). Designing in 3D should be done in all these parts and a document of demands has been created, with minimum requirements on the use of BIM to be able to use models in the production (Ljungberg, 2014). The document mainly contains demands for how to code objects with respect to location and building parts. This is based on guidelines in BSAB and AMA-codes (Ljungberg, 2014). Many demands in this document have been based on the type and level of demands that Trafikverket use in the upcoming contracts for *Förbifart Stockholm.*

4.3 Thoughts about BIM

Broo (2014) says that BIM is not used extensively in civil engineering. However, she mentions a few projects where it has been used, for example a tunnel project in Stockholm where a model has been used for machine guidance, and another project where an entire bridge was 3D modelled and approved by Trafikverket without being reviewed on 2D drawings. Another breakthrough is that in the Swedish civil project *Förbifart Stockholm* the request for tender consists of models. This means that the model got a greater legal status that 2D drawings and if dissimilarities occurs the model is applied (Ljungberg, 2014).

Broo (2014) also point at another tender project where Skanska Teknik 3D modelled parts of a road junction and used it for quantity calculations. She says that this model probably could have been used for other purposes as well. An issue that could arise when implementing BIM is whether all actors will have the ability to add information and how much information that is perceived appropriate to add (Broo, 2014).

As explained earlier, the design stage in SMB started before the tendering process was finished. In relation to this, Broo (2014) points out that working with BIM in the tendering stage could have been useful for the continued design since much of the information is re-used. She means that if the tendering design was structured in a better way it could have been used right away in the detailed design process. Furthermore, BIM can be used to find information easier (Broo, 2014). Today documents are somewhat scattered and hard to organise in a good way, which makes it hard to know where specific information is. For example it can be difficult to find previously performed calculations, what measurement that has been used, or assumptions that have been made. With BIM, information can be digitally stored in one place (Broo, 2014).

According to Nordberg (2014), cost estimations are today not conducted with the help of 3D models. But he thinks that if a model is coded in the same structure as the cost estimation, quantities can be extracted and imported into the estimation software rather easily. This is something that has only been discussed so far, but probably will be possible to do in practice soon (Nordberg, 2014). Furthermore, using models to help cost estimations would require that the model is finished in an early stage, preferably even before the estimation start. On the other hand, Nordberg (2014) also says that the benefits are not necessarily only connected to quantities. The illustration of time and space can be useful as well.

Even if Nordberg (2014) is positive to the implementation of BIM, he does not think that exporting quantities from a model into another format such as Excel and then further import it into Spik will create any benefits for the estimations itself, since the quantities are delivered in excel format already. The benefits are then instead connected to the person doing the quantity calculations. That is, if the quantity take-off becomes easier and more accurate than when using 2D drawings (Nordberg, 2014).

4.3.1 BIM implementation strategies

According to Ljungberg (2014), there is much going on with the implementation of BIM in Skanska at the moment. The civil construction operational area is taking initiatives about implementing BIM and establishing demands to encourage the use of BIM in every project. The idea is that these minimum demands should become more comprehensive as the organization adapts to the use of BIM. This work is established by working close to BIM-specialists who understand the software (Nordell, 2014). The BIM-coordinators work close to the designers and also within the production to support the implementation of new software.

Ljungberg (2014) says that he has noticed that the idea of using BIM has matured in the organization. Earlier the BIM-specialists had to sell the idea of BIM since no or little evidence of its advantages were evident. Especially, the use of 3D modelling is becoming more ordinary and the general attitude is that all projects should use it (Ljungberg, 2014). BIM applications that are used are generally surveying and machine guidance. Furthermore, Nordell (2014) point out that the enhanced interest has to do with that the operational area wants to enhance the productivity in the organization and therefore looks to the potential of BIM. To succeed at implementing BIM, Ljungberg (2014) says that demands on design need to be established so that the work performed in the design is of use in the production stage of projects. An issue, however is that if the demands are not set before the design starts, the level of ambition has to be lowered (Ljungberg, 2014).

Figure 21 shows how Skanska is working with implementing BIM. It illustrates traditional projects in the organization and how some projects are at the cutting edge, interested in new ideas and to try new technology (Nordell, 2014). The ide is to try new technology in projects to see what results it leads to and how this knowledge can be used in the future. It starts by creating lab-projects to try out ideas of improvement (Nordell, 2014). If the result is successful, the idea is taken further, into a pilot project. After this the results from the pilot projects are evaluated to see if the investigation was successful. To capitalize successful results of these efforts and to spread gained knowledge, development projects are created by BIM-specialists together with management at the concerned operational area (Nordell, 2014). This should lead to the creation of a package with a stable solution, including strategies for implementation, IT, support functions, and education. Ljungberg (2014), points at the importance of communication. If successful results of a pilot project are not communicated to the rest of the organization much potential is lost. Nordell (2014) says that this kind of knowledge feedback helps with implementing BIM in the organization. Additionally, according to Nordell (2014) it is important that results from pilot projects do not spread in the organization, since a complete solution for implementing it is not generated. When a new technology is implemented, BIM specialists are of great support in the project trying it for the first time (Ljungberg, 2014).

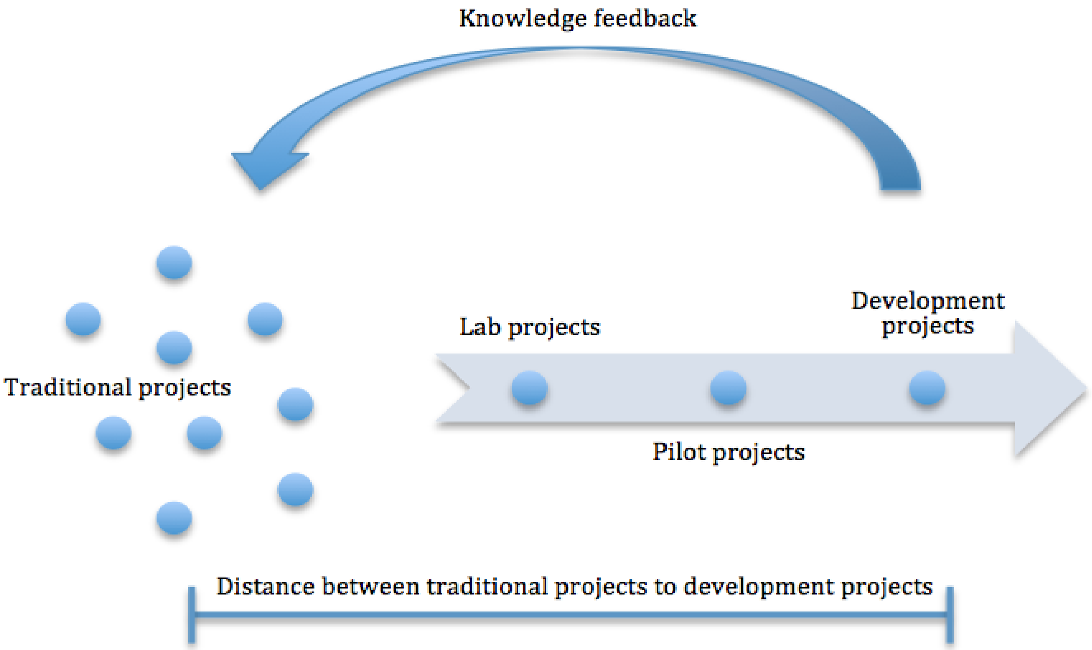


Figure 21: Strategy for implementing BIM.

According to Nordell (2014) it is important to keep the distance between cutting edge projects and traditional projects from growing. It is not desirable if some projects leap to fast and become very advanced long before other projects. It is important that the whole organization moves forward unanimously (Nordell, 2014).

As mentioned earlier Ljungberg (2014) says that in order to implement new technologies an organization needs to mature in the idea and that the timing needs to be right. When lab project are performed no general assumptions are made, not without considering the specifications of the project (Ljungberg, 2014). Results from lab projects are stored and considered in later projects. Ideas that did not work in one project might be successful in another and worth new try.

An example of a pilot study was to use an Ipad in the production as a journal, for conducting safety rounds and inspections. This gave good results and the use of an Ipad has led the discovery of additional advantages. For example the ability to bring digital drawings to the building site was useful in ordinary working processes (Nordell, 2014). Another point made by Ljungberg (2014) is that the drawings always are updated and synchronized. Additionally, the need to print drawings and laminate them decreases, which is both environmental friendly and cheaper.

The different interests in new technology makes it impossible to create one solution to fit all projects and all people working in projects. Some people are very interested and have computer skills while others just want to have a solution that works. According to Ljungberg (2014), work is right now focusing on lifting the lowest level to make people more adaptive to change. To enable this, Nordell (2014) says that BIM specialists will be placed in every region to support the implementation and educate people in new technology. Ljungberg (2014) explains that the demands set at SMB would seem very basic for some projects that have come further in the implementation, but is a challenge for other projects. For BIM-specialists the challenge is to support all projects without going to fast with cutting edge projects. Nordell (2014) further elaborates and says that there is a risk that some projects might feel that they are held back.

Comparing traditional working methods with BIM processes

In the effort to verify the benefits of using BIM it has been compared with the traditional way of designing. Historically, the information handed out during a tender has been studied and quantifications calculated based on this. When trying to apply BIM methods with software and programs used today there is an issue of interoperability. To solve this there is some intermediate stages, import of data from one program to e.g. excel, and then importing it into another program (Nordell, 2014). After adapting both methods, the differences in quantifications were studied. The result shows that both methods are valid and this will support the verification of BIM as it is useful in later stages of a project as well (Ljungberg, 2014).

To get away from all the import and export that has to be done the idea is to create a database were information is linked into the model. Another point made by Ljungberg (2014) is that changes during a project leads to much of work when working traditionally as often this means to start from the beginning. However, if working with BIM, and data is connected from to a database, this change will be put in the database one time and all models that are connected to it will be updated. Ljungberg (2014) explains that the approach to 3D modelling today is to push as lot information as possible into the models. One issue with this is that all information about the project is not available when working on the tender proposal and that much information is added during later stages of the project. An idea that Ljungberg (2014) is currently working on is to manage the objects in 3D, but storing the information on a data base that in an intelligent way is connected to the 3D model. This will not require that the person adding information knows the 3D tools. The cost for software licences would be lower as well as fewer people would work with the models. He also adds, that as a main contractor it is important to be able to handle all software programs depending of what software subcontractors' use. Furthermore, by using a database as source of information the 3D model would not be as extensive, hence less need for large computer capacity.

The option to use third party program, such as Vico or Tocoman iLink is something that is under considered according to Ljungberg (2014). Pilot studies are being conducted and the interest of connecting 3D information (geometries) to cost estimation and scheduling is of high interest. He further states that today it does not exist any tool that has it all, for example they "lock" the information to their own tools, hence the integration of various software is missing here as well. Nordell (2014) adds that the process of implementing BIM is an industry issue, all actors need to strive towards the same goal.

Difficulties

There are some difficulties and challenges to the implementation of BIM. According to Nordberg (2014) one of the biggest barriers today is the lack of knowledge. He means that expertise will be needed in order to implement it in the industry. This expertise would need an understanding for how the industry works, and be able to convince the organisations of the technology's potential (Nordberg, 2014).

To enhance productivity a critical factor is saving time and Ljungberg (2014) explains that he as a BIM specialist is faster at designing objects in 3D than corresponding material, such as views and sections, in 2D. The problem is that clients most often request 2D drawings for the maintenance which means that the 3D models loses its value, and if both 2D drawings and 3D models are created there will be unnecessary duplication of work (Ljungberg, 2014). This is because, despite what people believe, 3D models do not always generate 2D drawings automatically. This is because 2D models are simplifications of the reality based on an acknowledged language of symbols as oppose to 3D models that are closer to an illustration of reality. Furthermore, there is an increased workload to 3D modelling since effort needs to be put into the logical connection between the building objects. Nevertheless, if 3D models would be sufficient for the client, money would be saved in the design stage according to Ljungberg (2014). Nordell (2014) continue this argument by explaining that the general assumption is that it is expensive to design with BIM. He thinks that the focus has been misplaced since advantages for entire projects are not highlighted. One example is the use of models in production, which could bring benefits to a project and its costs as a whole (Nordell, 2014). However, the extent to which BIM is implemented in a project should be in proportion to the benefits. In small, simple projects full BIM implementation might not be necessary but rather increase costs (Nordell, 2014).

Another problem for the implementation of BIM is that the open file formats IFC and LandXML are not fully developed (Ljungberg and Nordell, 2014). Today IFC is connected to house specific building parts and not applicable to civil projects. There is a need to complement the standard with more generic object types. There is an initiative on EU level with the aim to produce an IFC standard for civil engineering, but this seems to take some time (Ljungberg and Nordell, 2014). Furthermore, IFC is not completed regarding house construction either. LandXML is a good format for transferring model information between software regarding points and lines, but surfaces and solids tend to be incorrect and inaccurate (Ljungberg and Nordell, 2014). The fact that data is lost or changed when exported and imported causes extra work since the information needs to be verified or in worst case recreated (Ljungberg and Nordell, 2014). Another issue with the open formats is that the software developers generally do not strive to support them. They rather want to “lock” the information into their own formats and cloud services. All these issues forces Skanska as a contractor to develop their own solutions to exchange information between different software. This creates a demand to know all software instead of becoming skilled at a few (Ljungberg and Nordell, 2014).

5 Discussion

One of the main questions in relation to BIM is if the benefits of implementing outweigh the costs and efforts of adopting it. In order to justify an increased workload in the design stage, it is important to know that the models can be useful later on in the project. Today it might not be possible to connect the entire chain of information with the help of BIM practices. This will require a big change to the work processes and the uncertainty of performance is large because of difficulties such as interoperability issues and lacking knowledge. In order to learn how to use BIM and what the benefits are, we think the adoption should be performed in small steps, and that the advantages need to be investigated in relation to project specific conditions in order to harvest benefits to overall project performance. Some projects might not gain from certain BIM applications, which mean that those applications probably should not be adopted until they are further developed and part of standard work processes.

As of right now, the implementation of BIM requires much duplication of work. This is a consequence of several different aspects. Firstly, the lack of standards and BIM knowledge makes it hard to fully connect information. For example, the lack of interoperability means that information cannot be transferred between different software but instead needs to be created several times. Secondly, most often the clients require 2D drawings for operation and maintenance, meaning that if BIM will be used, both 3D models and 2D drawings need to be created. This means that the design will be very expensive and time consuming. Nevertheless, we think that this will start to change soon. There are already examples of projects where only models are used and Trafikverket has approved the project on the basis of these.

5.1 Common input of cost estimating and scheduling

In order for a BIM model to be of use for other purposes than visualization, it needs to be coded in a satisfactory way. Since we mainly have studied the information needs for cost estimations and scheduling, we can only discuss the coding in regards to those two areas.

The main coding issue is to find a level of detail that fits both disciplines. As explained in the previous chapter, both disciplines in the reference project use location and building part as their coding structure. This is also the structure that is delivered from Skanska Teknik. The biggest difference between the disciplines is that the cost estimations have a much higher level of detail compared to the schedule. The schedule is very generalized and many activities are combined. This indicates that the level of detail needed for the cost estimations is the least detailed level that can be used in the model. This is because it is much easier to merge building parts or activities in the schedule than to split building parts in the cost estimations. As the previous chapter presented, the interviewees stated that it probably is not difficult to find a code structure for a model that fits both disciplines and their respective software. The basic structure for both is location and building part, but it is combined in different ways.

If the model is coded in this way quantity lists can be extracted and further imported into the scheduling and cost estimating software. In order to make use of models for these disciplines, the code structure needs to be set in an early stage since the scheduling and estimating are started almost as early as the design. Preferably, even the entire model should be finished before the scheduling and the estimating start. Creating the model early in the tendering stage is beneficial for the designers as well since they reuse much of the information from the tender stage in the design stage if they get the contract. This often means that some information needs to be created again. If BIM is used in the tender stage, the information would be stored and could be used again.

5.2 Handling the lack of interoperability

The lack of interoperability makes it hard to automate the flow of information between different software and disciplines. This creates a need for manual intervention, which leads to duplication of work and that some of the intended values of BIM are lost.

One way to handle this lacking interoperability is to use BIM software from only one developer for all modelling. On the other hand, this is hard to accomplish since all actors participating in the design have their own preferences regarding software. Another method for managing the interoperability issues is the use of IFC. The open format lets the project participants gather multiple models into one, and then use it for actions such as e.g. quantity take-offs. This seems to work relatively satisfactory in house projects, but the format is still long from functional in relation to civil projects. Furthermore, even if all actors used the same software or if the IFC format was fully developed, it does not mean that it enables a connected flow of information between disciplines. There needs to be a strategy on how the information from the models will be used in other stages than the modelling itself.

5.3 Connecting models to cost estimations and scheduling

The basic relation between cost estimation and scheduling is their dependence on quantity information from the design. The most fundamental way to connect models to cost estimations and schedules is to export quantities from the model and the import it in estimating and scheduling software. This does not create any automated information sharing since exports and imports are needed. Today it also requires much manual intervention. Furthermore, it does not necessarily create any benefits for the estimator or scheduler. In fact, this method does not make any difference for the estimating or the scheduling compared to the traditional way of working since the information is still delivered in Excel format. Instead the benefits are connected to the person doing the quantity take-offs.

Another way of connecting models to cost estimating and scheduling is to do all planning work, including cost estimations and scheduling, inside BIM software. When reading about BIM we have found that this seems to be the vision. The question is if this is the most beneficial way since it involves some difficulties, both technical and managerial. Firstly, if all planning should be conducted inside BIM software, many people from different disciplines need access to the model. This would mean that there will be a focus on inserting large amounts of information in the model. It also means that many people need to know how to use advanced CAD tools and that the risk for mistakes increases. It raises questions of responsibility. If one person changes anything in the model, who should be responsible if unintended changes have occurred? Also, questions of ownership and legal responsibility of the model arises if everyone has access to it. This could be solved if standards were established. Maybe people could have different types of right in the model, have access to different parts of the model and so on. If everyone should work in the 3D model, many expensive software license need to purchased. This generates additional costs as oppose to if only a few BIM coordinators worked in the software. There is also a high demand on computer capacity when working with such large quantity of data. To work in large 3D models can be slow if the computers do not have sufficient capacity. Both license and high capacity computers generate additional costs.

One way to connect models to cost estimations and scheduling and do the planning work inside BIM software is by using third party software, such as Vico or iLink. It is possible to work with some of the most common file formats, and much planning work can be conducted inside the applications. But if the project uses other planning and estimation applications, the use of third party software would still only create a semi-automatic information flow. The models would still be created in other CAD software, and there would be a need for exports and imports in order to use e.g. quantities in other scheduling and cost estimation software. The third party software is often compatible with leading planning software, but since some companies have developed internal systems and software the benefits cannot be fully utilized. In the case of internal software, such as Spik, this would mean that the information needs to be exported in Excel format and then imported into Spik. Because of this, we do not think that the cost estimations at the reference company would benefit from using these types of third party software, at least not if it is not possible to automated the information flow between the model and Spik. The benefit from using these types of software would, in our understanding, be the visualization, and the simplified and more accurate quantity extractions.

To solve the problems created when many people work in the same model, a database solution (Figure 22) can be developed. The objects, such as building parts, would be handled in a 3D model, but the information would be stored in the database and connected to the model in an intelligent way. This would eliminate the need for many people to work inside the model and the negative effects of this would decrease. It would also mean that if the database solution were created in an intelligent way, changes would be handled automatically. Everybody would not need to learn advanced CAD tools, but only be able to examine the 3D model and extract information from it. Instead a BIM coordinator should handle the model.

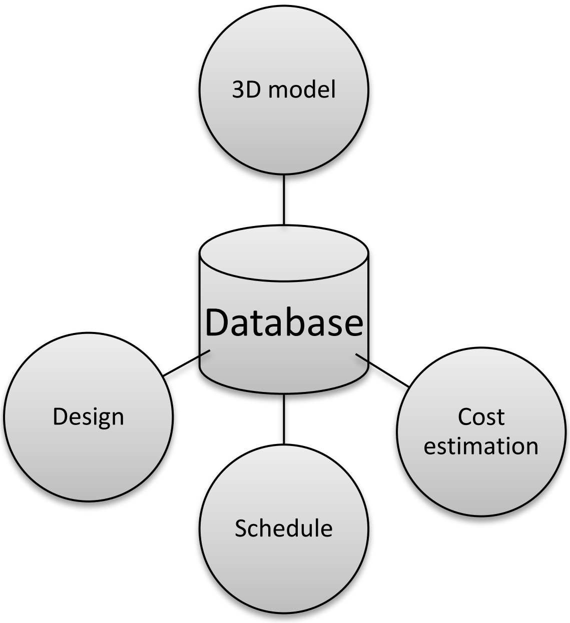


Figure 22: Simple illustration of a database solution where the objects are handled in a 3D model, but the information is stored in a database and connected to the model in an intelligent way.

5.4 Common understanding

Knowledge and understanding is required in order to create effective coordination strategies and structures. There need to be an understanding of other people’s work and how the BIM implementation will affect the work processes and the organization. This is reflected both in the literature as well as in the result gained from interviews. For the implementation of BIM to be as effective as possible it needs to be implemented by people who understand current work methods to be able to adapt the implementation in appropriate steps. Furthermore, a high level of cooperation is needed from all parties involved. Concerns, knowledge, expectations, etc. need to be communicated.

6 Conclusion

Based on the performed interviews in the reference project we think that today it is hard to fully connect cost estimation and scheduling to a model in an efficient way. It is possible to use BIM processes, but the lack of standards and knowledge means that there is a need for manual intervention, meaning that the flow of information is not fully automated. In this chapter the conclusions from this Master's Thesis is presented by attempting to answer the research questions stated in chapter 1.

How can BIM be used in relation to cost estimating and scheduling?

When investigating how BIM can be used in relation to cost estimations and scheduling, several different ways can be detected. The most fundamental relation between the two disciplines is that they are both relying on quantity information from the design. This information can rather easily be extracted from a model and then further imported into other software. However, this process does not in itself create any automated information sharing, but is based on exports and imports where manual intervention is needed. Also, extracting quantities from a model does not generate benefits for the estimating or the scheduling. In fact, for these disciplines this method basically does not differ from the traditional way of working since the information is still delivered in Excel format. Instead the benefits are connected to the person doing the quantity take-off. Another way to connect estimating and scheduling to a model is to do the planning work inside BIM software. An example is to use third-party software where the model is loaded and estimations and schedules can be created. However, we don't think that doing the estimations or schedules inside BIM software is the best solution for the reference company today. There are several reasons for this. The first reason is that the reference company has an internal estimation software called Spik. This system is developed to fit the organisation and is also used for other purposes than only cost estimations, meaning that it cannot be thrown away just like that. Hence, if estimations are performed in BIM software, the information still needs to be exported and imported into Spik, causing duplication of work and need for manual intervention. Another consequence of performing planning work inside BIM software is that many people from different disciplines need access to the same model. This means that many people need to know how to use advanced CAD tools and that the risk for mistakes increase. It also means that many expensive software licenses need to be bought. Furthermore, if many people from different disciplines should work inside the model, there will be a focus on inserting large amounts of information in the model. This means that information becomes locked to specific software and that large files are created which require advanced computers. To solve these problems we recommend a database solution where the objects, such as building parts, are handled in a 3D model but that the information is stored in the database and connected to the model in an intelligent way. This would eliminate the need for many people to work inside the model and the negative effects of this would decrease. It would also mean that if the database solution were created in an intelligent way, changes would be handled automatically. We should however clarify that we do not have the IT knowledge to fully understand how such a system could be created, but from the performed interviews at the reference company we have learned that such a system is not very far from reality. Future research on how to make the connection between models, estimating, and scheduling is needed.

What requirements need to be put on a model in order for both cost estimation and scheduling to benefit from it?

One of the initial aims of this Master’s Thesis was to find a code structure for a model that suits cost estimation and scheduling. We realized rather soon that finding a structure for a model is not the most complicated part when trying to connect it to estimations and schedules. This is because the investigated disciplines already use the same basic structure, location and building part. The important aspect is that the structure is set in an early stage of a project since the estimating and scheduling starts early.

What are the main barriers that hinder an effective implementation of BIM in connection to cost estimating and scheduling?

BIM has been widely discussed in the industry for a long time, but it is not until recently that it has started to be used in a more extensive way, especially not in civil projects. Still there are many barriers that hinder an effective implementation. These are mainly connected to the lack of standards and knowledge, and apply to the overall implementation of BIM and not only in relation to cost estimating or scheduling. Since there are no sufficient industry-wide standards on how BIM should be used, companies have to create their own solutions. This is of course necessary in order for them to move forward, but the question is how it affects the industry as a whole. To enable an efficient and effective collaboration with the use of BIM, we think it is vital that standards are established as soon as possible. Otherwise many different solutions will be created and used within different companies and the development for the industry as a whole will move slower.

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8 Figures