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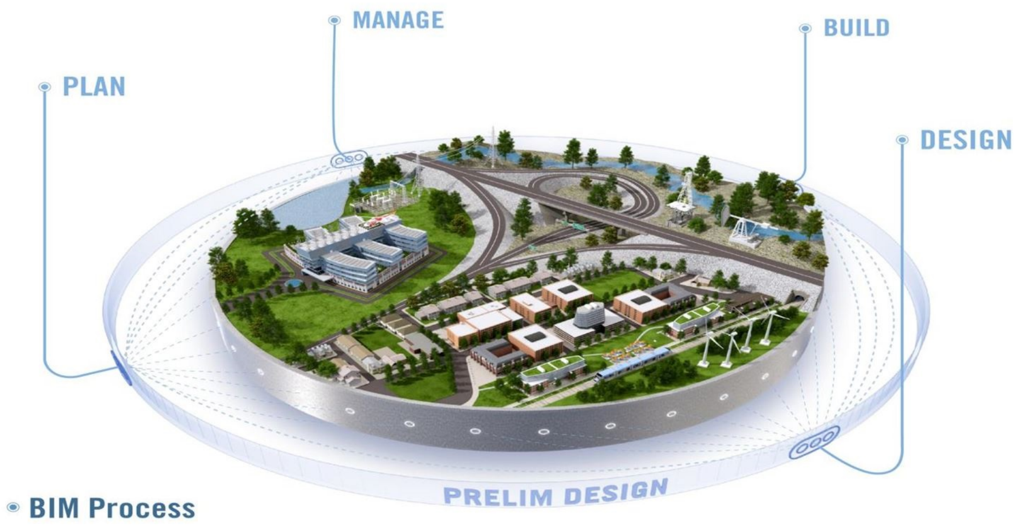

Use of BIM in infrastructural projects

A cross country comparative analysis between the use of BIM in Australia and Sweden

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

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CHALMERS UNIVERSITY OF TECHNOLOGY
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Master's Thesis 2014:159

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Cover:
The Building Information Modelling (BIM) process and the different stages in the process (Autodesk PR, 2014).

Chalmers Reproservice Göteborg, Sweden 2014

Preface

This Master of Science thesis has been carried out at the Department of Civil and Environmental Engineering, Chalmers University of Technology, Sweden. The project is a part of a bigger SBUF project with NCC Teknik och Hållbar utveckling in Gothenburg and Sustainable Built Environment National Research Centre (SBEnrc) in Australia.

The thesis has been carried out with Evelina Hjalmarsson and Maria Höier as researchers under supervision from Christina Claeson-Jonsson and Petra Bosch. The work has been going on from February 2014 to September 2014, including a research visit to Australia. Interviews with different actors in connection to project using BIM are the main information source in the thesis. Participated interviewees have been from the concerned Australian and Swedish companies.

Thank you Christina Claeson-Jonsson for your help providing us with relevant information and a work place at NCC's office in Gothenburg. Thank you Petra Bosch for the help during the work with this thesis. Your supervision and support has been really helpful through the work with the thesis. Thank you Keith Hampson and Adriana Sanchez Gomez for your help and expertise during our work during our time in Australia. Special thanks also goes to the staff of the two case studies. We would also like to thank Malin Andersson and Ilkim Görgulu for their help and feedback after reading our thesis.

Gothenburg September 2014

Evelina Hjalmarsson and Maria Höier

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ABSTRACT

The construction industry has a need and an interest of making the building process more efficient. One shared solution is to invest more time and money in the earlier stages of the projects. However, information and experience of using Building Information Modelling (BIM) in infrastructural projects is limited. The main aim of this report is to investigate how the use of implementing new information and communication technology, such as BIM, affects infrastructure projects. Two case studies, one in Australia and one in Sweden, have been performed to see the actual situation of the usage of BIM in projects. The thesis is a part of a SBUF project with NCC Teknik och Hållbar utveckling in Gothenburg and Sustainable Built Environment National Research Centre (SBEnrc) in Australia.

During the case studies several benefits and challenges were identified. In both projects visualisation and clash controls were of great benefit. During the design process a lot of time, money and work can be saved through 3D models. The clearest benefit is the work with clash controls before the construction starts. Integrated project delivery increases the opportunities for a successful project. The BIM technology allows an integrated approach to the design together with collaboration in early stages in the design phase generating a positive combination.

Key words: building information model, information and communication technology, integrated project delivery

Användning av BIM i infrastrukturprojekt
En jämförande analys mellan användningen av BIM i Australien och Sverige
Examensarbete inom Design and Construction Project Management
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SAMMANFATTNING

Byggbranschen har ett konstant behov och intresse av att göra byggprocessen effektivare. En gemensam lösning är att investera mer tid och pengar på tidigare skeden av projekten. Information och erfarenhet av att använda Byggnads Informations Modell (BIM) i infrastrukturprojekt är begränsad. Huvudsyftet i denna rapport är att undersöka hur introduktionen av ny informations- och kommunikationsteknik, såsom BIM, påverkar infrastrukturprojekt. Två fallstudier, en i Australien och en i Sverige, har genomförts för att se den faktiska användningen av BIM i projekt. Avhandlingen är en del av ett SBUF-projekt med NCC Teknik och Hållbar utveckling i Göteborg och Sustainable Built Environment National Research Centre (SBEnrc) i Australien.

Genom fallstudierna har flera områden av fördelar och utmaningar identifierades. I båda projekten har visualisering och kollisionskontroller varit till stor nytta. Under projekteringsfasen kan det sparas mycket tid, pengar och arbete genom 3D-modeller. Den tydligaste fördelen är användandet av kollisionskontroller i projekteringsfasen innan byggandet inleds. Integrerad projektleverans ökar möjligheterna för ett lyckat projekt. Ett användande av BIM-verktyg möjliggör en integrerad syn på design samt samarbete i tidiga skeden i designfasen vilket är en fördelaktig kombination.

Nyckelord: byggnadsinformationsmodell, informations-och kommunikationsteknik, integrerad projektleverans

Contents

Notations

AIA - American Institute of Architects

BIM - Building Information Model or Building Information Modelling

BlueView - Internal communication tool

CAD - Computer Aided Design

D&C - Design and Construct

ICT – Information and Communication Technology

IPD - Integrated Project Delivery

MBRL - Moreton Bay Rail Link

QTMR - Queensland Transport and Main Roads

TMR - Transport and Main Roads

2D - Two dimensions: x and y

3D - Three dimensions: x, y and z

1 Introduction

This chapter will present the background and the problem definition of this master thesis. The purpose and aim of the thesis will also be presented followed by the objectives, limitations and the research questions. This chapter also includes a description of the context of each chapter in the thesis.

1.1 Background

The construction industry has a constant interest of making the building process more efficient. One shared solution is to invest more time and money in the earlier stages of the projects. The usage of precise planning and designing the overall process in detail decrease the risk of making mistakes further on in the project. The use of building information modelling (BIM) in the construction industry has increased during the last years (Linderoth, 2013). When using this technology, one or several parts of a project are constructed digitally in a virtual model (Eastman, 2011). By this, model support can be used in the design phase, and improve analysis and control in a project. In addition to design models there are also models that include information regarding time planning, financial management, calculations and simulations (BIM Alliance, 2014). When working with BIM it is useful to define different levels of BIM as well (Building Information Managament, 2011). There are three levels from 0 to 3 and the purpose of defining them is to categorise types of technical tools and techniques that are used. More information about the different levels can be found in chapter 2. The benefits of using BIM have been discussed throughout several studies and one of the most visible benefits is within in the design phase (Linderoth, 2013). However, there is a need of noticeable positive results in the production phase to get the companies more interested. There is a large amount of literature on BIM that primarily highlights the benefits of using BIM (Eastman, 2011). BIM has primarily been applied in larger infrastructural projects such as building houses, hospitals, and offices. Since infrastructure often comprises large and complex projects with many partners involved and focusing on a long term perspective including maintenance, the use of BIM might be beneficial to study. Companies in the construction industry are willing to increase the use of BIM, but they also want to have a guarantee that the use of BIM will be beneficial for the project. Companies are not willing to risk something that might work if they can choose a safe alternative were they have knowledge and earlier experiences. This study is therefore important and will hopefully contribute and help companies in the construction industry to clearly see the effects generated through the use of BIM.

1.2 Objectives

The main aim in this report is to investigate how the use of new information and communication technology, such as Building Information Modelling (BIM), affects infrastructure projects. The objective is to give a clearer view of the effects of using BIM in the earlier stages of infrastructure projects, as well as define the concept and levels of BIM. Through this, organisations receive better knowledge of the importance of implementation and usage of BIM in more efficient ways, and also understand what level of BIM that is required for different projects and stages.

This thesis is based on an on-going research project by the Sustainable Built Environment National Research Centre (SBEnrc) in Australia, NCC Teknik och Hållbar utveckling and Chalmers University. The research will focus on the design processes and the implementation of new information and communication technology through two case studies based on a document review and interviews in Australia and Sweden. At a later stage in this thesis, a cross-country comparative analysis will be used to see similarities and dissimilarities between the countries.

1.3 Problem definition

The use of BIM in the construction industry is rapidly growing, but the use of BIM in infrastructure projects is still relatively low. There is a lack of information, both theoretical and practical, about BIM in infrastructure projects. This research aims to gather data and build an understanding of the current situation through a cross-country analysis of the use of BIM in infrastructure projects. This report aims to investigate how implementing new information and communication technology (ICT), such as BIM, affects infrastructural projects. With this as a basis, the following research questions have been created in this study.

Main question:

How does the implementation and use of new ICT, i.e., BIM, affect infrastructure projects during the design phase?

Research questions:

RQ1 What does the design process in the specific infrastructure projects look like?

RQ2 What types of procurement arrangements regarding BIM are used in the projects?

RQ3 At which level is BIM implemented in the different projects and how is it used?

RQ4 Can specific effects of the utilisation of BIM be identified in terms of usage?

1.4 Limitations

To limit the scope and the choice of case study projects, a checklist of the wanted stage and type of project was formed. The chosen projects suitable for this report is two on-going infrastructure projects in an early stage of the design process where the use of BIM should be a central point in the project planning stage. The sizes of the chosen projects were rather similar to get the most out of the analysis. To allow the cross-country analysis, the location of the chosen projects was another central restriction. One project was placed in Australia and one project was situated in Sweden.

1.5 Thesis outline

Chapter 1 introduces the subject of the report, the background, the objectives together with limitations and the research questions.

Chapter 2 describes the theoretical background and the basic knowledge in the main areas of information of this research, for example design processes and information and communication technology.

Chapter 3 presents the method used throughout the work process during this thesis.

Chapter 4 presents the results from the case studies and the interviews including an analysis of the cases. Some recommendations for future work is mentioned in the end of the chapter.

Chapter 5 includes the discussion of the research results.

Chapter 6 presents the conclusions of the report.

2 Theoretical Background

This chapter describes the theoretical background with a focus on BIM, but also design processes, public and private organisations, information and communication technology, new ways of working and integrated project delivery.

2.1 Design processes

The design process can be divided into five phases, (i) architectural program, (ii) schematic design, (iii) design development, (iv) construction documentation, and (v) construction. The most essential decisions are usually made in the earlier stages of the design process. In large and complex projects it is useful to use a collaborative design. This requires numerous individuals and groups cooperating throughout the design process. It is important for all involved parties to share their information and organisational design tasks (Chiu, 2002). When a group of designers, contractors and suppliers collaborate their work with BIM they share their information with each other (Geospatial Today, 2014). The project team can develop and share their BIM models to improve the quality of the capacity. This collaborative process provide a deeper understanding and the models can be used in a way to facilitate the collaboration among the involved parties, from design through construction.

Earlier studies have shown that issues of the design collaboration often are found in the process, team works and the design settings but the focus of the organisation is often forgotten. Chiu (2002) insinuates that a structured organisation can simplify the design communication and contribute to better achievement of the project. Since design processes involve a diversity of stakeholders, i.e., clients, architects, contractor and structural engineering, there has to be a constant exchange of information and knowledge during the process. It is important to understand how the people are organized in the process, how the organisation affects the communication and if the computer systems can facilitate the collaboration. To solve specific problems and to achieve goals, a design organisation has to exist. Communication represents a sender and a receiver. Some classic problems in design collaboration are media problem, semantic problem, performance problem and most critical the organisational problems.

2.2 Public and private organisations

There are differences between public and private organisations. A big advantage for public organisations is their capability to gain knowledge, while one of the biggest advantages for public organisations lays in their capability to share knowledge through their social networks. Public organisations focus on people and communities interests while the private organisations focus aims to expanding the economical profits (Hyang-Soo & Seong-Hoon, 2013).

Public organisations finance their projects with money from the society and therefore they have harder restrictions on the procurement process. The public procurement act is a way to control the process and allows all companies in the industry to participate in the tendering process. The process is more time consuming than for private organisations, but it is a non-discriminating process were companies get the same opportunity to participate and be equally treated (Sveriges riksdag, 2007).

2.3 Information and communication technology (ICT)

Information and communication technology (ICT) consists of different types of new computer-based tools to enhance the management of architecture, engineering, construction and facilities industries (Froese, 2009). A tool like this could be building information modelling (BIM) which has the main purpose to enhance effectiveness and efficiency of designing and managing construction projects. Communication is often perceived as a major difficulty for design collaboration. Next to face-to-face communication, the construction industry is also looking more and more into the use of ICT to support the design process. Indicators for projects success in terms of knowledge work could be communication and interaction (Bosch-Sijtsema & Henriksson, 2014). Communication and knowledge work can partly be supported by ICT. The construction industry is a project-based industry where complex projects are performed in which many different stakeholders are involved. ICT can support a part of the collaboration between the different stakeholders.

Bosch-Sijtsema & Henriksson (2014) claim that earlier studies show that difficulties appear in projects-based industries of extracting, distributing and applying knowledge across both cultural and structural boundaries. Moreover, this makes it more complex to cooperate when the knowledge is averse, situational and locally embedded. In regard to knowledge work, communication and interaction (i.e., ICT, 3D models) are observed to be indicators for project success. Another aspect that the literature highlights is that communication is one of the main concerns in the construction project environment. In construction projects, many stakeholders are involved in the design process, i.e., contractor, clients and architects. In this stage there is a need of information and knowledge exchange. Furthermore, the development of new working methods is discussed and examples on this could be concurrent design, extreme collaboration and use of ICT and visualisation. These different working methods intend to improve the interface between the stakeholders. Focus on parallel processes is used in several of these methods, moreover work in teams that are multidisciplinary and the use of ICT. To share embedded knowledge and practice based knowledge can be enhanced by the use of ICT is confirmed by knowledge management literature.

Ways of working have been affected by new ICT in many industries (Bosch-Sijtsema & Henriksson, 2014). Studies regarding ICT implementation have resulted in identification of key implementation drivers and difficulties (Vachara Peansupap & Walker, 2006). In the construction industry these are beneficial when providing a strategic view of the implementation of ICT success. The studies also showed barriers of the use of ICT, furthermore the adoption to the construction industry. Some of the highlighted barriers that were common in the studies indicated low knowledge of ICT and investments levels. Peansupap and Walker (2006) explain that there are few studies that examine the implementation constrains of ICT in the perspective of innovation diffusion at the organisation, work team and individual level.

Innovation in relation to ICT refers to the introduction of new ICT initiatives to an organisation (Vachara Peansupap & Walker, 2006). The process in an organisation when introducing ICT initiatives can be described as ICT diffusion and a definition of ICT diffusion constraint as a resistance to change motivation when implemented and adapting to new ICT. Resistance can appear at different levels; personal, organisational and group. In order to improve ICT diffusion processes for the construction industry, understanding of diffusion constrains could be beneficial. Also, finding ways to alleviate possible ICT implementation diffusion barriers are important to the diffusion process.

Below we focus on one type of ICT that is currently used in the construction industry, i.e., Building Information Modelling (BIM).

2.4 Building information modelling (BIM)

In regard to how the facility delivery process operates today, a large amount of the communication is commonly paper-based (Eastman, 2011). This way of working often leads to errors and deletions occurring and can cause delays and costs. The implementation of computer-aided design (CAD) systems started out in the 60s and 70s in the architecture, engineering and construction industry (Jongeling, 2006). Engineer´s 2D drafting work where speeded up by electronic drawing boards. The accesses of basic 3D modelling applications already existed at that time but were expensive and limited for expanded companies and had not the potential to provide that technology. In the 80s the technology developed and it became more commonly to have a personal computer instead of mainframe computer systems. This made it possible for the CAD applications to branch out in the construction industry. The applications advanced from the mainly usage of 2D drawings to a better adaption to 3D modelling during the nineties. The technology has continued to develop and todays CAD system have greater potential for more than 3D modelling. In spite of the fact that the technology is more comprehensive than before, the construction industry mainly use document when exchanging information. One of the most promising developments within the construction industry is Building Information Modelling (BIM).

2.4.1 What is BIM?

When using BIM technology, one or several parts of a project are constructed digitally in a virtual model (Eastman, 2011). By this, model support can be used in the design phase, improve analysis and control in a project. BIM fulfils the possibility to integrate functions that are needed in a projects' lifecycle. This accommodates construction qualification, new design and modification of a project team's roles' and relationships. The implementation of BIM has in recent years increased within the construction industry (Linderoth, 2013). Expectations on that BIM will contribute to the development and efficiency on the construction industry processes have existed for more than a decade. When BIM is applied well in a project it enables an improved integrated design and construction process, furthermore better quality and reduced time and cost (Eastman, 2011).

"Building Information Modelling (BIM) is a set of interacting policies, processes and technologies generating a "methodology to manage the essential building design and project data in digital format throughout the building's life-cycle." (Succar, 2009)

Furthermore, it is important to have a clear definition of what BIM is and why it is used. In addition to design 3D-models there is also models that include information regarding *time planning, financial management, calculations* and *simulations* (BIM Alliance, 2014). There is not always obvious what BIM stand for and sometimes no clear boundaries exist, this could therefore cause confusion in different situations. *Building Information Model* and *Building information Modelling* is often used to define what the term BIM implies. In this report BIM is defined as a modelling technology that embraces the process of communication, produce and analyse building models (Eastman, 2011). Four criteria have to be fulfilled in order to use the concept BIM;

(i) Object-oriented components in the model that include information about what they are.

(ii) Properties are linked to the components in the model, information about how they behave.

(iii) Data in all views in the model is coordinated.

(iv) Consistent data and interactions between the different components.

When using BIM, different ways of working are required; the focus on the lifecycle of a building or structure changes the way of creating, sharing and using data (Eastman, 2011). Using BIM also affects support of the facility industry by stakeholders such as architecture, engineering, construction, real estate, ownership, and finance within the facility lifecycle. BIM can accomplish great advantages during the whole lifecycle of a project (Teicholz, 2013). The models and the information can be used throughout the whole project to save time, effort and money not only in building but also running and maintaining the building.

2.4.2 Levels of BIM

When working with BIM it is useful to define different levels of BIM to clarify the concept (Building Information Managament, 2011). One way to identify different levels is to divide them into three levels from 0 to 3. The purpose of defining them is to categorise types of technical tools and techniques that are used. This will make the understanding and the use of BIM more detailed for the client. Today varies the experience of working with BIM within the building sector and therefore can levels of BIM aid the understanding. In Figure 2 are the three levels illustrated and what these include.

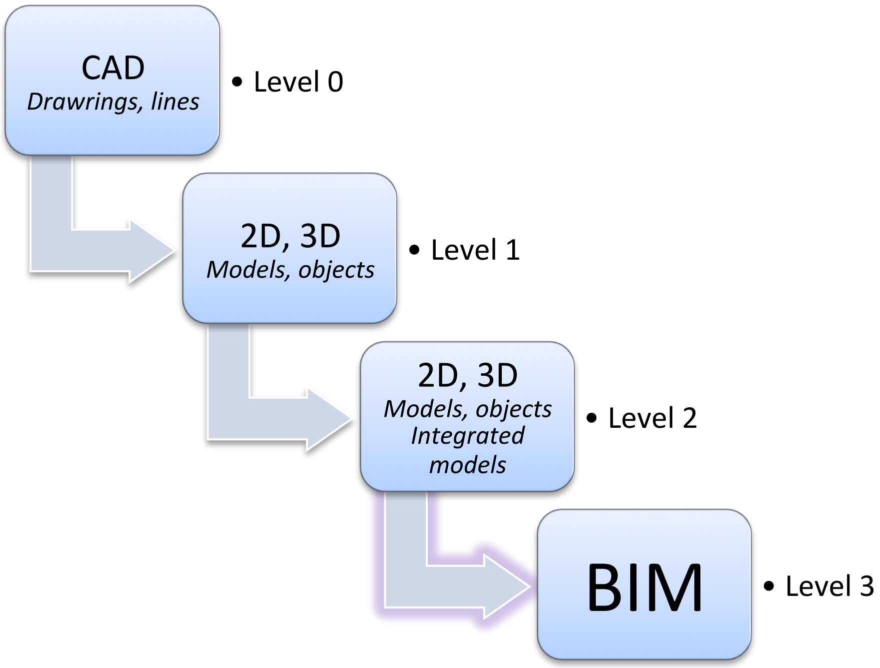

Figure 1 *Levels of BIM* (ArchiTECT-BIM, 2013)

Definitions of the different levels:

Level 0: This level contains unmanaged CAD, most likely 2D (both paper and electronic) (Building Information Managament, 2011). Often used as a tool to communicate alternative design and visualize the project (DPR Review, 2010).

Level 1: CAD in 2D or 3D format that have been managed by the design team (DPR Review, 2010). The models include for example mechanical, electrical and plumbing systems (MPE), now in a higher level.

Level 2: 3D environment with attached data is managed with BIM tools and the detail lever is higher (Building Information Managament, 2011). This could be a detailed model created by MPE subcontractors that are combined with models made by the designer (DPR Review, 2010).

Level 3: At this level the model has the capability to test the construction, do clashes controls (DPR Review, 2010). Also look for example at the best materials, and design in accordance with the projects budget, schedule and quality.

2.4.3 BIM impact

Advantages with BIM that have been acknowledged up to now can mainly be associated with the design phase (Linderoth, 2013). Moreover, it could be stated that advantages exists with the production phase as well when using BIM. This could be that in advance discover collision which then could be avoided in the production and consequently avoid additional work. When using visualisation in construction projects the opportunity for feedback on the design emerges. Furthermore the discovery if the project does not fulfil the requirements to be useful.

When working with CAD systems, everything that is being made composes digital files (Eastman, 2011). Plotted drawings are produced by older CAD systems. Furthermore the generated files contain layer identifications, vectors and associated line types. As a development of this, information can be added to the files, and also superior and advanced surfacing tools can be added. The technology was further developed and it became more interesting to share data connected with specific design instead of drawings and 3D images. Models that have been done with a BIM tool have the possibility to support different views of the data that is included in a drawing, containing 2D and 3D. A model can describe different entities, e.g. information about its content or its capabilities.

However, implementation of BIM in organisations has social impact on individuals, the organisation itself and the profession (Deutsch, 2011). Also, by understanding how the social communication, culture and collaboration impacts on the firm the implementation of new technology like BIM will be much smoother. Deutsch (2011) is referring to Autodesk's Phil Bernstein who says:

"The productivity and economic benefits of building information modelling (BIM) to the global building industry are widely acknowledged and increasingly well understood. Further, the technology to implement BIM is readily available and rapidly maturing. Yet despite the obvious benefits and readiness of BIM software, BIM adoption has been slower than anticipated. Why?"

Among design professionals the adoption of BIM is not widespread, even if an uptake of the new technology has happened rather quickly (Deutsch, 2011). Also, in some cases where the adoption of BIM occurs it is not always remaining after the project. In those cases where the adoption has been successful it is because of human factors and not because of technological of business factors. Other factors that affect the result of adopting could be to have the wrong people working with it, incorrect attitudes and mind set.

As stated before there are a lot of benefits when working with BIM, integrated design and business benefits are some examples (Deutsch, 2011). To encourage the benefits of the tool, changes in thinking are often promoted but at the same time lack of insights concerning communication and workflow that are important for successful outcomes could appear.

When introducing new technology like BIM it is essential to consider what changes could appear within the organisation (Linderoth, 2013). A central part regarding this is the understanding of the interaction of new technology dimensions, the organisation where the new technology will be implemented and the organisations environment. Introducing new technology will have an impact to the organisation. It is hard to foresee the impact and the effect on how people work with the new technology.

2.5 New ways of working

Project delivery of large projects consists of different integrated content and software through standardized processes, which form a digital infrastructure (Jaradat et al, 2013). In order to provide high quality data to owners and operators, use of technology is motivated. Good project management systems have always been needed for clients to manage projects teams successfully. In order to accomplish this and the right degree of professional collaboration and combination in management, design and production several fragments are carried out. One fragment could be that through information systems the organisational design of the project team and the distribution of skills is increasingly mediated. As a result of that new technologies are being used and changes is required to project processes, protocols and practices.

When using the tool BIM with the main purpose to enhance effectiveness and efficiency of designing and managing construction projects, changes in work tasks and skill sets of the team members in a projects is required (Froese, 2009). Using new ICT that are increasingly complex requires that the information system must be clearly managed with a high degree of collaboration and integration across project tasks. As a result of this, difficulties often appear when emerging ICT and adapting the technology into current practice and be able to take full advantage of such systems. Further, challenges arise when professionals work closer in projects, such as new roles can be developed (Jaradat et al, 2013). Transfer and standardisation of digital data can be an issue when the consultants might use different systems and therefore different types of file format. Jaradat et al (2013) describes how professionals can perceive large digital systems as not as flexible as people and could therefore be sometimes unreliable, time consuming and interfering to a project. New integrated digital systems are seen as helpful in several ways but require more integration across professional roles and simultaneously professionals have to handle new challenges and issues. Since technical systems are not as flexible as people the judgment from the professional is still significant. When a technology such as BIM is used with integrated data, that reform the process of delivery development of new roles with more intensive knowledge is required during the process of delivering and managing infrastructure and buildings. Projects within construction are complex due to the amount and interdependency of their components, further project management methods strive to increase integration of different project views by making these interdependencies obvious (Froese, 2009).

2.6 Integrated project delivery (IPD)

IPD is a project delivery approach that uses the expertise and views of all project participants through all phases of design and construction (AIA, 2014). It is a way to optimize the project results, increase value to the owner, reduce waste, and maximize efficiency through the phases of design and construction (AIA, 2007). Integrated projects are significant by effective collaboration between the owner, designer and the constructor. Unlike the traditional project delivery, the IPD consist of an integrated team including the key project stakeholders that has been assembled early in the process, and consist of an open and collaborative work process. The process starts with early inputs of knowledge and expertise from the involved stakeholders and the information is openly shared with trust and respect. The risks are collectively managed and appropriately shared between the stakeholders. The reward system is based on the team success in combination to the project success and is value-based. A digitally based form of communication is often used with digital based technology such as virtual BIM in 3, 4 and 5 dimensions. The IPD principles can be applied to different agreements in order to encourage, promote and support open sharing collaboration with risk sharing. Integrated projects can be identified as an effective collaboration (including the owner, the designer, and the constructor) starting at early design and continuing throughout the project until project is finished.

The American Institute of Architects (AIA) creates altered guides and has formed agreements for three different levels of IPD (AIA, 2014):

(i) *Transitional Forms*

Existing agreements have been used as a basis to form new arrangements that offers an easy and understandable step into IPD

(ii) *Multi-Party Agreement*

An agreement that can be used to design and construction using IPD

(iii) *Single Purpose Entity*

Creates a limited liability company that allows complete sharing of risk and rewards in a fully integrated collaborative process

An integrated approach to the building process can be developed through early collaboration and the use of BIM (AIA, 2007). The BIM technology allows a more integrated and virtual approach to the design and construction of a project, together with early collaboration the opportunities increases for a successful project. The AIA works together with other construction industry stakeholders and try to collaborate with industry leaders to facilitate the dialogue and share knowledge with each other. They also try to present the benefits of the collaborative approaches to public and private sector clients in a way to promote changes that allow early information sharing. Likewise, the benefits of using a virtual model are being promoted in order to show how the integrated and collaborative team of project stakeholders (owners, designers, consultants, constructors, subcontractors and suppliers) can work together.

3 Methodology

This chapter presents the process of the work with this thesis and also explains the research design and how data was gathered.

3.1 Process overview

As mentioned in the introduction, this thesis is related to on an on-going research project, and the subject of the report was already determined before the work with the thesis begun. Still some modification was done to narrow the subject of the thesis.

This research aims to determine productivity benefits generated by implementing Building Information Modelling (BIM) in transport infrastructure construction projects. The research focuses on the design processes and the procurement arrangements through two case studies based on a document review and interviews in Australia and Sweden, with the aim to find practical results applicable to other projects. At a later stage, a cross-country comparative analysis will be used to understand how to further increase productivity in other projects through the use of BIM.

The working process was divided in seven parts as shown in Figure 3. Even though the subject of the thesis already existed, the subject had to be specified. The specific aim of the thesis was formed in the problem definition and thereafter the research questions were defined. The next step in the progress was to start the literature review to collect information about the selected subject to gain a wider and deeper knowledge. The interview questions were created in a relatively early stage and formed in a way to be able to answer the research questions. Since the thesis' aim is to compare two projects in two different countries and their use of BIM, the same interview questions have been used in both countries. Thereafter, the interviews were held and additional information was gathered and analysed. Finally, the outcome of this analysis was discussed and is presented in the discussion chapter and the conclusion sums up the outcome of this thesis.

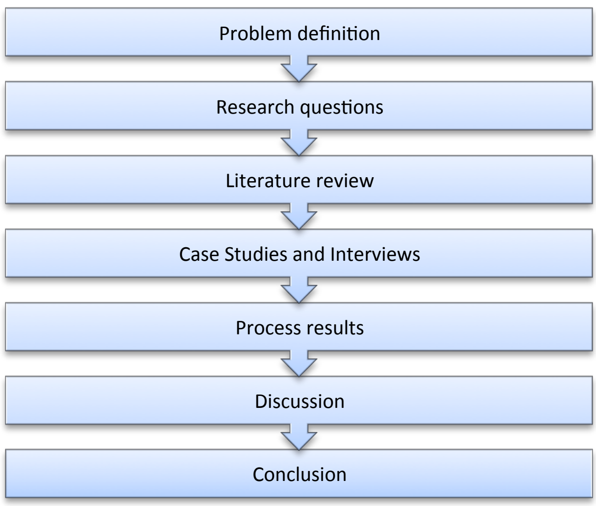

Figure 2 The working process of the thesis

3.2 Informing the research

Research design and research method are two aspects that are important to separate (Bryman & Bell, 2011). Research design describes how the collection and the analysis of data will be performed, while the research method defines how the data was collected. The gathering data consist of two major methods; qualitative and quantitative research. A qualitative research aims to give a deeper understanding of attitudes and ideas were words are more important, in comparison to a quantitative research were statistic and mathematic methods are used to give a wider scope of information. A case study is a common research design supporting qualitative data collection, because of the detailed information that is gathered. The information in this thesis was collected by two case studies and a total of ten interviews.

3.2.1 Case studies

A case study aims to make a general statement and a precise description of a case (Flick, 2009). It is problematic to identify a case that is significant for the research questions. When extent findings are generalized it is considered as a weak source in a qualitative research. In order to discover the variation and the differences of case studies, it is important to include a small number of cases. One perspective is to choose similar cases and try to find similarities and patterns for generalisations. Another perspective is to choose cases as different as possible to enable general conclusions and to find similarities. This report is based on two case studies, one in Sweden and one in Australia. The selection of the cases was carried out in collaboration with Curtin University in consultation with Chalmers University and NCC Construction Sweden. One important selection criterion was that the cases would need to be as similar as possible in order to compare them across two different countries.

The cases have been chosen because of their location, type and size. The locations of the projects were the main requirement. Since the aim of the report is to compare the use in Sweden and Australia, the cases had to be located in these countries. To be able to conduct a relevant analysis it is useful to compare similar types of projects, in this report the cases had to be infrastructure projects in the earlier phases of the project. As mentioned above, the goal with the case studies is to see how the implementation of BIM affects the projects. Therefore, the chosen cases had to be infrastructural project where BIM has been used during the planning and design phase. The size of the project was also of great importance, since the cases already were situated in two different countries, it was important to analyse two projects with similar size.

3.2.2 Qualitative data collection

The data collection has been performed through semi-structured interviews with people working in different parts of the construction industry. Interviews were conducted with individuals within three main categories of the construction process: (i) the client; (ii) designer; and (iii) contractor. The categorisation of their roles will be useful later on to facilitate the analysis. Also, the interviews were held with people working with the selected project for the case studies, which reduced the selection of companies.

Since every individual is a unique being they also have their own way of thinking and looking at the projects. The specific role of each interviewee might also affect his/her answer to the interview questions. It is important to be aware that the information gathered during an interview comes from this particular interviewee. Another employee working at the same project with same tasks might answer same question in another way. This is one of the limitations with using interviews as a data collecting method (Bryman & Bell, 2011). Even though this limits the credibility, interviews are useful to get personal and honest answers. An interview allows more and specific questions, which is useful to get a deeper understanding and wider answer to a question.

The interviews in Australia were carried out with help from the research assistant Adriana Sanchez, who already had been in contact with companies in Australia. The first contacts information and details were gathered in cooperation with her. One main contact helped to contact other suitable interviewees involved in the project. The interviews in Sweden were carried out in a similar way. The first contact was with the client, and through more conversation it lead to several contacts with the involved companies.

3.2.3 Interview questions

An in-depth semi-structured interview follows a reasonably unstructured pattern and has an approach that allows the respondents to describe their opinions and views instead of simple answer e.g. yes or no (Gilmore & Carlson, 2007). This method helps to: (i) cover a wider area of interest; (ii) identify and explore the key issues; and (iii) gives opportunity for further examining until mutual understanding is reached.

To accomplish and collect useful material from the interviews, information about the companies and their organisation were investigated before the interviews were held. This information gave basic knowledge and enabled the development of the interview questions. Relevant interview questions could then be formed to get the most out of the interviews. The questions can be divided into four categories: (i) background information of the infrastructure project; (ii) use of BIM in the project; (iii) knowledge of BIM in the project; and (iv) outcomes from using BIM.

3.2.4 Interviewees

In order to conduct and gather right the information it is important to select the interviewees based on pre-defined criteria. The selection criteria for the interviewees were that they: (i) have a key role within the infrastructure construction project; (ii) have knowledge and experience of the use of BIM in the actual project; (iii) access to relevant and correct information that could be used as basis for the case studies; and (iv) are willing to participate in an interview. Table 1 demonstrates the chosen roles and companies of the interviewees.

A total of ten interviewees have been held during this research, five in Sweden and five in Australia. The interviews were generally held at the companies office and each interview took approximately one our. All interviews were audiotaped with the respondent's consent.

Table 1 Organisations and roles that were interviewed in the projects

Actor	**Role**	**Australia**	**Sweden**
Client Organisation	Project Manager	Queensland Transport and Main Roads	Trafikverket
Designer	BIM coordinator CAD System Manager	Hassel Aurecon	ÅF Grontmij
Contractor	Site Engineer	Theiss	NCC (not procured)

3.3 Analysis

Information from each case was analysed separately and thereafter a cross-country analysis was made. The information from the performed interviews was the basis for the analysis. Both Australia and Sweden contributed with similar, but still varied, information that was useful to the analysis.

When the interviews and the case studies were finished, the analysis started. The results from the case studies were compared with each other. First, the benefits and challenges by working with BIM were identified. Thereafter, the cultural differences between the countries were studied to see if they affected the process when working with BIM. One

The cross-county analysis was made to see if there exist any similarities or dissimilarities between the chosen case studies. Since the studies are situated in different countries, this is already a big difference between the results, but still there are similarities among the countries. Both Australia and Sweden are countries with a rather low habitation in comparison to its size, their economies are relatively strong, the economical development is similar to each other, and both countries are monarchies with similar political climate.

4 Results from the Case Studies

Chapter 4 presents the outcomes from the case studies. The results and information gathered through the interviews in Australia and Sweden are also presented. First the result from Australia is presented, followed by the result from Sweden.

4.1 Australia, Moreton Bay Rail Link

The first case study was located outside Brisbane in the Moreton Bay region in Australia. This region is one of the fastest-growing local government areas in the country (TMR, 2010a). Shopping centres, childcare centres and schools are being built to keep up with the increasing interest in this region, and this development requires public transport for the inhabitants. New constructions and infrastructural changes have an impact on the nature and it is important to maintain a high environmental standard to lower the environmental impact.

The Moreton Bay Rail Link is a public transport project that will provide the region with a high volume passenger rail line (TMR, 2010b). The rail line will be 12,6 kilometres long and will have six new rail stations along the track. A shared path for cyclists and pedestrians will follow the whole rail line to facilitate the line access.

The Australian Government, Queensland Government and the Moreton Bay Regional Council provide the project economically (TMR, 2010c). The Queensland Government, through the Department of Transport and Main Roads (TMR), is responsible for the delivering of the project. The project is planned to be completed in 2016 and deliver a cost-effective and faster travel alternative.

The tendering for the project consisted of four steps (Queensland Government, 2014). The first step was the release of the projects Request for Proposal and an outline to the procurement process. Thereafter, four tenderers were shortlisted, and in the third step these four tenderers became two and had to develop designs and submit cost proposals. Finally, on August 1st 2013, the chosen contractor was awarded the contract to design and construct the Moreton Bay Rail Link.

Implementing BIM in the project

In the first phase of a project it is essential to define what will be included in the project before the design process starts. The architect states that it is very important to know what level of BIM is going to be used in the project, and also what detail level is required in the specific project. In the beginning the architect creates a so called 'BIM framework', which is a document listing exactly what is expected from each consultant, what the end result will be and if the document will include 2D drawings or 3D models. The application area is decided as well, if the drawings should be used only during construction or if it used also for operation and use. All of these aspects need to be signed off before the project can even start to make sure all involved actors are aware of the instructions. As stated before, it is important to decide what level of BIM is going to be used, and the level is documented in the contract at the very beginning of the project. The Moreton Bay Rail Link contract requires a delivery of 2D drawings, but to get a better result the architects made their own decision to also produce 3D models.

During one of the interviews the project manager stated that it would be too expensive to have any other part modelled in 3D, therefore it was decided early in the project that only one railway station should be modelled in 3D during the tender process. The model of the station is very similar to the other stations in the project, and can therefore be used in relation to them as well. This 3D model is used as a visualisation, but also to be a part of commercial promotion. Furthermore the model is not used as a foundation in the construction work and cannot be built from.

The contractor is using a modelling system consisting of several different tools, but the project manager does not want to call it BIM because of the different definitions of BIM. In other words there is not only one model used, instead different areas and different products like AutoCAD, Revit, SPACE GASS, 12D model system are used and an internal communication tool called BlueView brings the information together.

The 3D model developed by the architects in the project is called a *federated model* and consists of models from different consultants: architecture; hydraulics; electrical; and structural. To be able to work with BIM in the project different software programs are used. AutoCAD and Revit are used for 2D and 3D models; Navisworks is used as a collaboration tool and also for coordination and clashes. A modelling package for civil engineering projects called 12D model system is also used.

The architect also explains when Navisworks is used in the project it is possible to receive a lot of information, one example regarding this is to choose a place in the model you would like to go to and Navisworks draws a map of how to get there. Navisworks can also make clash controls, which shows various clashes in the model and this tool is often used in the project. When Navisworks shows the different clashes in the model it is also possible to get a report of all the clashes and shows where they are and all information that is needed to find them.

Use of 2D and 3D models on site

The federated 3D model will be used on the construction site and everyone on site will have access to the model and be able to look at it on laptops. The surveyor on site receives the design and sets out the project through the 12D model that has been designed earlier in the project. The 12D model goes to another system called Terramodel, which is a specific surveying tool that enables surveyors to set out the project coordinates on site. One example of this are that the trucks that are moving material from one point to another will be linked in to the survey model system and the coordinates that have been set out on site. Furthermore, there is a connection between the design and the surveyor on site through the survey model system, Terramodel. Also, the equipment used for shaping the profile has a receiver and will automatically be controlled by the stations through Terramodel. Terramodel has been used in earlier projects but is very efficient in combination with BlueView, BlueView will be described below.

The contractor is also using a GIS data based system called BlueView, which is an internal communication tool used at the construction site. BlueView is used to see 2D drawings in different layers, where AutoCAD and 12D models are converted into the tool. At all times the contractor can log on to BlueView with an iPad and see the progress of the project and the design. The tool can also show what has been done in the project so far and who to contact regarding different areas. Additionally, there is a checklist used to get an improved overlook of what has been done and what should be done. The GPS in BlueView helps to point out the exact location on site, this makes it possible to see exactly what changes and who is on site. It is also possible to take photographs as a device to send and ask questions and bring up specifications with the project manager. Also using FaceTime, a phonecall with camera, is possible. This application could be used to call the project manager and ask questions about the actual situation and other simple questions such as “this is what’s happening here”, “did we agree to this”. The call also allows the worker to show the project manager around on site through the camera if necessary. BlueView is a new tool for the workers in this project, even though the contractor had a little experience of BlueView. By using this new tool the application change how people work on site through the parts included in the tool stated above. Another aspect regarding BlueView is that it is not possible to change any file in the application, just see the different layers. All of the information will be stored and you can go back and see what happened, past events.

Benefits

Both the project manager and the architect states that the most essential benefits with the use of BIM are that construction issues can be solved with clash detection before it comes to the construction site. The model could also cover unknown issues that will come up later on in the project. The contractor thinks that it is essential to have access and the possibility to get drawings that show the clashes before the construction begins, this will reduces the variations when they get to construction site.

Every consultant is doing their respectively model and afterwards the models will be joined into one federated model. The consultants are collocated in the same office building, it is quite unusual and they are very grateful for this opportunity. Working close to each other improves the collaboration and communication. The collaboration seems to be successful and saves a lot of time so far in the project. This way of working makes it easier to go directly to each consultant regarding questions about the model or something else about the project.

Other benefits in the project are obtained from the Terramodel system that makes it possible to track the materials and trucks on site. This improves a lot of logistic aspects and preparation, thereby a lot of time and money can be saved. When this tool is used the possibility to communicate increases tremendously. With the ability to contact important roles in the project, such as the project manager, through BlueView at any time and have a FaceTime conversation about a possible problem to solve makes the work very efficient.

Challenges

One of the biggest challenges of using BlueView is to get the right information in the right amount. This tool provides a lot of information about the project and makes it challenging to get the right information at the right time. A challenge is to not overload the tool with information, because an overload would make the system useless. There are always difficulties, for example to convert information from one system to another. Furthermore the project manager states;

"No one is ever happy, it is always a problem"

To use the tool BlueView as efficient as possible it requires an understanding and knowledge of how to use it with the right amount of information. Moreover, the project manager thinks that the project is too big to be able to combine every part in one model and call it BIM. Additionally, the development of working with 3D models and implementation of BIM is not of greatest priority because of lack of time and resources. The project manager stated that the overall the product is working well, but it is how you bring all the parts together and that is what the GIS BlueView is trying to do.

4.2 Sweden, the Stockholm Bypass

The Stockholm Bypass is one of Sweden's largest infrastructure projects and the project started in 2006 (TRV, 2014a). The project consists of 21 kilometres of road where 18 kilometres is going through tunnels, which is a decision being made in consideration to protect the natural and cultural values.

The population in the Stockholm region is going to increase with 400 000 inhabitants the following 20 years (TRV, 2014b). This increase requires a new and fully working traffic system and the project Stockholm Bypass aims to give new transportation opportunities. The Stockholm Bypass will help to decrease the traffic pressure in the central parts of the city, and also other road accesses to Stockholm, since there's only one road between the northern and the southern parts, and this road passes through the central part of Stockholm.

Implementing BIM in the project

In the beginning of the project there existed no clear instruction that BIM was required to be used in the project. The head of major projects at Trafikverket wrote in the project description that the use of BIM should be used and developed. The technical manager for the Stockholm Bypass at Trafikverket, and two other persons involved in the project saw the opportunity to work with BIM in the project. They worked hard to implement BIM in the project. In the contracts with the consultants it is not stated that BIM is mandatory but 3D models and models for inspection are required. Trafikverket also claimed that every consultant should have two new roles in the project, a model coordinator and a model pilot, this was a condition for the implementation. The model coordinator and model pilot have the knowledge and experience of the different softwares and competence of how to use them. The consultants then have the opportunity to get help when lack of knowledge occurs when using new technology. Also, the consultants learn from the model coordinator and model pilot and develop their skills to use in this project, but also to use in future projects and collaboration with Trafikverket. During the design phase the term BIM has been more used and developed. As mentioned before only terms as 3D models were used in the beginning of the project but during the design phase the term BIM has been more implemented. The reason for this could be that people who is working in the project gains more knowledge of what BIM is and feels more confident to use the term.

For the construction document phase new consultants were required and a design description for these consultants was created. All consultants should be using 3D CAD models. Some of the consultants had worked with 3D models before in other projects and others were less experienced. No one of the consultants complained about this decision. The technical manager believes that not everyone was aware of the actual demands from Trafikverket. In this project they would actually be working after was what written in the specifications. Once the work started, the consultants had to learn the new tools and the new way of working, to help with that they all had a model coordinator and a model pilot as stated above. The main difference when working with 3D models instead of only 2D drawings is the possibility to generate drawings directly from the 3D model and the challenge to keep the workload at a manageable level.

Level of BIM

All consultants use the same level of BIM when they deliver the model to Trafikverket, and this level is perceived by Trafikverket to be rather high. The models delivered to Trafikverket from the consultants determine what level of BIM is used. There is a guideline value that should be fulfilled when working with BIM. Some of the guidelines should be achieved, and that includes one or more object-oriented model is made. Properties are linked to the objects to some extent and the models have properties linked directly or indirectly to the objects. In the models the possibility to have links between the objects is not available, instead the files are marked in a certain way to know what information is in the file. Although, all of this is not possible to keep in the models when they are delivered to Trafikverket, when the different models are put together the links between the objects disappear.

The use of BIM

In the plan stage, Trafikverket already started using 3D visualisation called VR-models, which was mainly for inspection; this was the beginning of the use of BIM. Some of the designers made 2D drawings directly from the VR-models, one example of this is bridge structures. In some cases the VR-models were built from other peoples' work and sometimes 3D-CAD models were brought into the VR-models. Regarding bridges, this was not possible; instead the drawings were used as a foundation for 3D pictures. A 3D model was created and the model made it possible to give a distinct view of what the project would look like. In this model some information were linked, information could be geotechnical investigation points that showed that they were at the right place. In the model it was also possible to see significant information regarding mud and other materials. This provided the option to see in the model what the review points showed and other information. This was the first step towards the use of BIM in the project Stockholm Bypass.

Trafikverket is working towards more collaboration with design and build contracts; hence they have consciously removed some parts. During the design phase detailed models have been created to review and make clash controls. The model included in the contract is a stripped-down model, and the main purpose of the model is for legal basis in the contract. Also, they are partly stripped models in order to minimize control of the specifications for the contractors. Furthermore, the exchange format is complete to facilitate the management of the models. When Trafikverket procures a contractor Trafikverket has the possibility to provide the complete designed model if desired. The finished model will be used as an accommodation during the production where machine management and earthworks are some examples.

Benefits

In the project and the design phase benefits of working and implementing BIM have been identified. The main advantages are expected for the consultants during the design phase, as well as for the contractors during the construction phase. One of the benefits when working with BIM in this project is easier coordination, which saves time and money. In the next phase of the project the main advantages will probably be clearly shown, in terms of errors and defects are very few and the control over the facility will be more extensive. One essential part of Stockholm Bypass is to have current data between the consultants; correct information regarding different parts will be built in the right order. What has been designed in the first phase will exist in the next phase, working with BIM will hopefully lead to these benefit.

A 3D model of a complex facility is much easier to understand, for all involved in the project as well as society actors, than the various drawings from different areas of technology. The understanding of how it all fits together is the biggest benefit of working with BIM, moreover collision controls and better security controls. When the right amount of information is selected from the model and can be interpreted correctly, the benefits will increase.

Some of the advantages are connected with the disadvantages. It is important to get an overview in a virtual model but many of the specialists cannot interpret and understand the models. The model can unfortunately not be fully utilized because of the new technology, and the risk for misunderstanding increases. There have been some technical problems during the work with BIM in this project, especially because of the lack of knowledge of the new technique. Software suppliers have recognized this problem and are becoming more aware of the problem. A number of technical specialists on the client side review and approve the consultant’s work. They are doing this gradually over the work process to reduce errors and bugs in the early stages of the project.

However, there was an unfamiliarity of working with so-called viewers, such as software like Navisworks. There are a lot of commands and functions that have made it difficult for many specialists to deal with and actually get into the program and see any pictures. To get a better understanding the two new roles, the model coordinator and model pilot, helped and showed how the application work and how to use it. Trafikverket underestimated the complexity of the programs or overestimated employees' knowledge.

Challenges

To get a common standard has been the most challenging regarding the use of 3D models and BIM in this industry. It has been a challenge to both Trafikverket and consultants to start thinking object-oriented. This includes the process of going from drawings to object-oriented models, where each object has all the necessary information. This has taken a lot of time and this has also made it more complicated to handle the different files and data. Moreover, it means that all consultants should be facing the same direction, making it possible to actually exchange data with each other.

The deliveries from the consultants have had an unexpectedly high level. Within the industry the attitude regarding working with BIM has changed from inexperienced to realise the importance and the essential parts of the new technology and ways to work. Internally within Trafikverket uncertainty is increasing, new and more problems have occurred regarding the use of BIM and technical problems create uncertainty within project management.

From a BIM point of view, the procurement is a barrier that requires Trafikverket to be formal and to take part of equal conditions, and not to provide good BIM solutions, because everything has to be neutral. Different soft wares have different ways to use BIM solutions. BIM benefits to the Stockholm Bypass will take a major turn when the construction phase begins and there are contractors on site that can discuss and agree what software and format to use. Further, the designers have developed a lot and learned a lot on how the systems should be used, a major development that they will benefit from in the future. 3D models in contract documents have never been used before, not even in house building sector. Trafikverket is trying to get a legal contract system included with the models and BIM specifications and this ambition will go further within Trafikverket and will probably be a basis for future procurements. The possibilities and the potential of using BIM are huge. The amount of paper drawings is extremely few and big part of the information is available in the model created during the design phase. The greatest opportunity for Trafikverket is to continuously save information for the maintenance phase.

When the project started is was decided it would be up to the consultants which program to use. This led to a use of approximately 35 programs. Trafikverket made the compromise to allow any type of software for design but the delivery is required to be in exchange format. Due to this, a lot of intelligence disappears in the delivery stage, but in return it is ensured the possibility to open the model and look at it.

The dilemma with BIM in the construction industry in 2014 is that it does not exist any open standards and good format. This means that Trafikverket must rely on markets formats. As a conclusion of this, Trafikverket has not been sufficiently tough in the requirements definition. One example of this could be to not prohibit certain types of objects that it has been established to cause trouble. However, this is a difficult balance because more limitation causes more efforts and costs for the consultants.

4.3 Cross-country analysis

The projects in the case studies are at different stages in the construction process. The project in Sweden, the Stockholm Bypass, has not fulfilled the tendering process but the project in Australia, the Moreton Bay Rail Link (MBRL), has been procured and is under construction. Because of this, the use of BIM and the results from the interviews are rather different. The results from the Stockholm Bypass project interviews cover information about the implementation of BIM in the project, also planned to be use in future projects. The results from the MBRL mainly contain information about the use of 3D models and BIM at the construction site. During the design process the architect in the MBRL project asked for a BIM framework, but the interest from the project manager at TMR was not to the same extent, mostly because of time, resources and economical aspects. In the Swedish project the goal is to design as much as possible in BIM and develop open standards, in this project but also to use in further projects at Trafikverket.

To clarify the outcomes when implementing BIM in infrastructural projects, a list of the expected effects is stated below:

(i) Improved collaboration between the different consultants and actors in the project

(ii) Clash controls during the design phase

(iii) 2D-drawings directly from the BIM

(iv) Implementation of existing useful ICT and open standards

(v) Difficulties and challenges in new ways of working

It is difficult to confirm that the implementation of BIM will lead to these benefits before the project is completed, but there are strong indications that it will happen. The interviewees have highlighted these benefits and believe that these outcomes will occur during and after the projects.

During the case studies several areas of benefits and challenges were identified. In both projects visualisation and clash controls were of great benefit. During the design process a lot of time, money and work can be saved through 3D models. Especially with clash controls, this was something that was pointed to a large extent in both projects. Moreover, the BIM in Stockholm Bypass had the opportunity to generate 2D drawings from the model and a lot of time and work could therefore be saved through 3D models.

Furthermore, it was observed that a clear cultural difference between Sweden and Australia exists. In Australia, the role of the architect is significantly stronger than in Sweden. This was clearly shown in the use of BIM, that it was the architect who worked for implementation and a higher level of BIM in the project. However, this was only shown in the parts of the project that was modelled in 3D, the railway stations. On the other hand, the project in Sweden is not yet procured and therefore it is more difficult to analyse the architect influence in the project in regard to the use and implementation of BIM.

During the interviews it was discovered that BIM was used more in Sweden compared to Australia. The conclusion of this could be that cultural differences exist between the different countries. People in Australia seem to have a higher self confidence and are willing to show their expertise and promote new ways of working. People in Sweden are more withdrawn and do not show their expertise in the same way. The differences may also occur due to the fact that the project in Australia is in the production phase, while the project in Sweden is still in the planning and design stage.

Furthermore, companies need to take their BIM use to the next level. It might require higher demands from the authorities such as new legal aspects and new laws. If there are higher legal demands, construction companies have to make a change, and that might be what it takes to make a change in the use of BIM. If there is no legal demand, companies do automatically choose the same pattern as before. Integrated project delivery may increase the opportunities for a successful project. The BIM technology allows an integrated approach to the design together with collaboration in early stages in the design phase is a positive combination.

In the future, when BIM hopefully is more implemented in the construction industry, time, resources and money will be saved and the investment will be valuable. When measure the results and positive effects of implementing BIM that will facilitate the work and make it more intelligent will lead to better decision-making. Based on the findings, further investigation can be done where it is possible to examine the effects that were identified from both projects, it could be motivating to ascertain whether the effects fulfil the expectations.

5 Discussion

Chapter 5 includes the discussion part with the research questions as a basis including recommendations for future work.

The main aim in this report is to investigate how implementing new information and communication technology (ICT), like building information modelling (BIM) affect infrastructure projects. In order to implement ICT such as BIM in a project it is important to decide what should be accomplished in the beginning of the project and what should be stated in the tendering contract. Implementing new ICT to a project requires a change of the working progress.

5.1 Culture

Even though Australia and Sweden are two rather similar countries, there are still a lot of differences between the countries. The countries' culture diverges which might affect the working process. In Australia the architect have a stronger role than the architect have in Sweden. It was especially clear when studying at the use of BIM, in Australia the architect was the one pushing for implementing a higher level of BIM.

Before the interviews were held, the people in Australia spoke very positive about BIM and the use of visualisation in the current project. This gave high expectations to the thesis and gave a rather clear view that Australia had advanced knowledge in working with BIM. But during the interviews in Australia, the expectations and the use of BIM in practice were not as high as predictable. This can be compared to the expectations of the use of BIM in Sweden. Before the interviews, people spoke carefully about the use of BIM in the current project. The expectations of the use of BIM in Sweden were therefore not as high as in Australia. During the interviews in Sweden it was discovered that BIM was used in a much higher extent than expected. The project in Australia is in the construction phase while the project in Sweden still is in the planning phase and this might be one of the reasons to the different amount of using BIM.

5.2 Development of new ways of working

As explained in the previous chapter, when working with new technology, change is required to project success, protocols and practices (Jaradat et al, 2013). In both projects, the Moreton Bay Rail Link and the Stockholm Bypass, work is being done to develop and create new ways of working when applying new ICT such as BIM. In the Stockholm Bypass a lot of work is being done to develop and improve new standards when working with BIM, the main goal is to use this technology completely in the project and also in further projects. Further, as described above, the contracts with the consultants did not state that BIM is mandatory in the Stockholm Bypass project, but 3D models and models for inspection are required. As a result of this, new ways of working are required and knowledge regarding the new tools is a requirement. As mentioned earlier, Froese (2009) states that new ICT are complex to adapt and requires that the new technology must be clearly managed with a high degree of collaboration and integration across project tasks. In the MBRL project the new application tool BlueView is a convenient new way to work when applying 3D-models into the project. Through this tool, the collaboration increases and also integration across project tasks. BlueView makes it possible to take advantage of 2D- and 3D-drawings in another way than it had been done before in other projects. Also, the combination of BlueView and Terramodel makes the work on the construction site more efficient and makes it possible to use models in a new way of work.

5.3 Development of new roles

As described earlier, Jaradat et al (2013) explains that new roles can be developed when professionals works closer in projects. Further, large digital systems can be perceived as not as flexible as people and can therefore sometimes be unreliable, time consuming and interfering to a project. In the Stockholm Bypass project it was a requirement that two new roles had to work with the consultants during the project. When the project started, the consultants had to learn the new tools and the new way of working, to help with that they had a model coordinator and a model pilot. In previous chapter it was described that technology like BIM with integrated data that reform the delivery process, development of new roles with a greater knowledge is required during the project. Due to the minor implementation of BIM in the MBRL project, the development of new roles in the project was not the same extent as in Stockholm Bypass. Knowledge regarding the new tool BlueView was needed but no roles in the project because of it did not exist.

5.4 Public organisations

The analysis of this report includes two public organisations, Trafikverket in Sweden and the department of Transport and Main Roads (TMR) in Australia. The fact that both the organisations are public may affect the way of working with the project. The procurement might follow the same structure as in earlier projects, and the focus on the economical profits can be ignored. This doesn't have to be something negative, but it is important to be open for new alternative ways of working. New ICT can be costly and public organisations need to take economically risks to develop new ways of working.

5.5 Benefits

It was declared before that when using BIM technology, model support can be used in the design phase, improve control and analysis in a project (Eastman, 2011). Also, that BIM makes it possible to in advance discover collision in the model, this reduces problems in the production and consequently avoid additional work. During our research the result was confirmed by this theory. In the research the following benefits were identified when working with 3D-modelling and BIM:

(i) Increased understanding by team members through visualisation

(ii) Clash controls during the design phase

(iii) 2D-drawings directly from the BIM (in the Stockholm Bypass project)

In the MBRL project both the project manager and the architect states that the most essential benefits with the use of BIM are that construction issues can be solved with clash detection before it comes to the construction site. Further, the model could also cover unknown issues that will come up later on in the project. As explained previously, BlueView and Terramodel make it possible to track the trucks and materials on site. This is one of the greatest benefits when working with these tools in the project, with improved control and model support.

In the Stockholm Bypass project is was also found that the main advantages are expected for the consultants during the design phase, as well as for the contractors during the construction phase. One of the benefits when working with BIM in this project is easier coordination and also the ability to get 2D-drawings directly from the model. Other benefits that were identified in this project were the understanding of how it all fits together when working with BIM through visualisation, moreover collision controls and better security controls. When the right amount of information is selected from the model and can be interpreted correctly, the benefits will increase.

5.6 Challenges

To increase the use of BIM there is a need for standardization, especially for the object structures and the exchange formats (Knight, 2012). There are different programs to use when working with BIM. One problem is that different software collides with each other, which leads to a loss of information. This is something that needs improvement. If information is lost when merging data, there is no point in using BIM. The best solution would be if all the involved parties used the same program. There is also a problem with getting the right information and the right amount of information, or else the BIM system will be overloaded and the system will crash.

Another challenge is the habit of working with digital data information. The construction industry is rather conservative and the workers do not have experience of working with BIM, which leads to problem when implementing new ways of working. The workers need to have an interest to learn and be willing to put effort in the learning process to be able to develop the use of BIM.

When working in a project several people are involved and each and everyone has their ways of looking at the same project. People come up with new ideas, they compare their ideas to each other and they come up with new solutions to problems. Each individual have their thoughts and ideas, and they share their ideas with each other. They present their ideas in texts, sketches, drawings, CAD drawings or other digital images. Ideas are presented and received in different ways by each individual. This is something that may lead to problems and misunderstandings. Therefore, it is very useful to find one common way to communicate and present ideas and thoughts in a project.

6 Conclusion

This chapter presents the conclusions from this Master's Thesis by attempting to answer the research questions stated in chapter 1.

What does the design process in the specific infrastructural projects look like?

The Moreton Bay Rail Link project started out with a request of proposal to find interesting tenderers, and thereafter one final contractor was awarded the contract to design and construct the MBRL. The architect created a BIM framework as a base to the project. This document contained information of what is expected from each consultant, during the project until the final product.

The Stockholm Bypass project did not have any specific demands or instructions concerning BIM. The demand came from the project itself when the technical manager and two other involved persons wanted a higher level of the implementation of BIM. Thereafter it was decided that the consultants should be using 3D CAD models. The main difference when working with 3D models is the possibility to generate drawings directly 3D model to keep the workload at a manageable level.

What types of procurement arrangements regarding BIM are used in the projects?

In the MBRL project, where a D&C contract has been used, the entrepreneur generates the drawings and constructs the building. With a BIM aspect there is only one requirement that has to be followed, and that is what level of BIM that are going to be used in the project. As mentioned in the result, the architect creates a BIM framework, a document containing exactly what is expecting from each consultant, what the end result will be and if the document will include 2D drawings or 3D models. When this is complete it is important to decide what level of BIM that is going to be used, and the level is documented in the contract in the beginning of the project. In the MBRL project only one part of the project was modelled in 3D, which was one of the railway stations. Although, the way of working has been enriched by the use of Blueview, which is a type of BIM software. This tool has been improved and developed during the work, further to the new technology and the use of BIM. In Sweden the project is not yet procured, but it is most likely going to be a design and build contract were the entrepreneur gets document with simple demands on the design, create a new design from the demands from the owner of the project and thereafter construct the building. The tender documents will be made in BIM as much as possible, and probably also stated in the contracts when the project is procured.

At which level is BIM implemented in the different projects and how is it used?

Implementation of new technology is difficult and requires resources, time and money. The architects in the MBRL project appeared to have much interest and knowledge to implement BIM in the project. In Sweden, Trafikverket is working hard to implement BIM in the project and develop BIM standards that can be used in future projects. It is hard to define what level of BIM has been used in the different projects.

One reason might be that there are no fixed standards yet. As described in chapter 2.3.2, one way to identify the specific BIM use is to divide BIM into four different levels, from 0 to 3. Although it is hard to categorise and decide what level the different projects belongs to. The level of BIM used in the Stockholm Bypass could be stated as a level 3. Technical aspects get in the way, but that is a part of the implementation and development of the new technology. In the MBRL project the level of BIM is estimated as a level 2 for the railway stations and a level 1 for the rest of the project. With this as a basis, the implementation could be further developed in future projects and reach the best possible outcome when working with BIM. More literature and research in this area could help and simplify the categorisation when deciding to what level a project belongs.

Can specific effects of the utilisation of BIM be identified in terms of usage?

Throughout the interviews and case studies it has come clear that the most obvious benefit from using BIM in early stages of the process is to find clashes before the construction work has started. This makes it easier for the workers during construction and saves time. To discover a clash at the site during construction often have negative effects. The time plan is often negatively affected and often results in delays for the project, which in also creates negative economic effects. The use of BIM helps to visualise the project for all involved parties and increase the understanding of the process. Implementing new technology like BIM requires knowledge, time and money. The Stockholm Bypass invested in implementing BIM and how to handle projects when working with BIM and has, therefore, made progress in new ways of working. The implementation and development has not only occurred within Trafikverket, but also their consultants have developed their work as a result of the requirement of what to deliver to Trafikverket. The project in Australia has not made the same investment to implement BIM in the project to the same extent.

One of the challenges with the use of BIM is when file format from different software collides with each other which results in a loss of information. Something has to be improved to help the use of BIM in the right direction. It is hard to tell which software is the best and which software that should be used by all companies, but there has to be a change and development of the software.

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Appendices

Appendix 1 – Interview questions

Generic/Background

1. Can you please tell me about your role in the project?
2. At what stage is the project now?
3. How was the design process conducted?
    a. What type of procurements arrangements have been used in the project? What type of contract?

Use of BIM in the project

We would like to understand how BIM have or will be used in this project. There are different levels of BIM, from simple 3D CAD to fully integrated 3D models that include cost and scheduling information, and are based common data environments.

4. At what stage in the building process was it determined that BIM should be used?
    a. Before or after the tender process?
    b. Who decided that BIM should be used?
    c. Is BIM legally binded by contract? How specified?
5. What level of BIM is used?
6. What are you using or have planned to use the model for?
7. To what extent was BIM used and at which stages?
8. What was the role of the various actors in terms of BIM during the design process?
    a. responsibilities
    b. decision-making points
9. Has the use of BIM influenced how you are cooperating in the design team during design?

Knowledge and use of BIM

10. How was the knowledge level of BIM at the company before the project started?
    a. Has the company used knowledge from previous similar projects during the design process?
    b. How many of the people involved in the project have experience with BIM and can use it?
    c. Was any education of BIM needed in the company or did the company use external knowledge?

Outcomes from the use of BIM

11. What have been the main advantages of using BIM during the design stage?
12. What have been the main disadvantages of using BIM during the design stage?
    a. Were there any technical problems with the software during the modeling?
    b. Any other problems (not technical) with using BIM in the project (e.g., cooperation, information sharing, resistance to use BIM etc.)?
13. Has the use of BIM developed during the work?
14. What opportunities do you see when working with BIM?
15. Can you identify any specific effects of using BIM?
    a. Time
    b. Economical
    c. Legally
    d. Productivity
    e. Resources