SBUF

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NCC

STYRNING I ANLÄGGNINGSBYGGANDE GENOM DIGITALA MODELLER

En jämförande analys mellan användningen av BIM i Australien och Sverige

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FÖRORD (Swedish)

Denna rapport bygger på ett samarbete mellan NCC Teknik och hållbar utveckling, Chalmers tekniska högskola och *Sustainable Built Environment National Research Centre* (SBEnrc) i Australien vilket syftar till att hitta nya vägar att lyfta anläggningsbyggandet.

Det praktiska arbetet med efterforskningar, intervjuer och dokumentation har utförts av Evelina Hjalmarsson och Maria Höier genom ett examensarbete inom *Design and Construction Project Management* på NCC Teknik och hållbar utveckling samt Institutionen för bygg- och miljöteknik, Avdelningen för Service Management, på Chalmers tekniska högskola.

Arbetet omfattade litteraturstudie, fallstudier samt intervjuer. I detta ingick en resa till Australien för att där utföra fallstudier och komma i kontakt och intervjua personer som dagligen i australiensiska byggföretag arbetar med BIM i anläggningsprojekt samt personer på SBEnrc som är involverade i det australiska forskningsprojektet *Integrated project delivery – Productivity Gain through Industry Transformation*. Det är från denna resa som huvudparten av resultatet presenterat i denna rapport baseras på.

I examensarbetet, och för utvecklingsprojektet, vill Evelina och Maria rikta speciellt tack till examenarbetshandledaren på NCC, Christina Claeson-Jonsson, samt på Chalmers, Petra Bosch, för handledning, goda råd, underlag till arbetet, alla kontaktytor, samt all praktisk hjälp med bl a arbetsplats på NCC och resa till Australien. Vidare tack till Keith Hampson och Adriana Sanchez Gomez på SBEnrc för hjälp i och med vistelse i Australien samt expertis i ämnet, samt till all personal i byggprojekt som stödde i fallstudierna. Slutligt tack till Malin Andersson och Ilkim Görgulu som hjälpte till med att granska examenarbetet.

Projektet vill speciellt tacka Svenska Byggbranschens Utvecklingsfond, SBUF, och NCC Construction Sverige som med sitt stöd har gjort det möjligt att genomföra denna studie.

Studien presenteras här på engelska inklusive en svensk sammanfattning.

Göteborg mars 2015

SAMMANFATTNING (SWEDISH)

Byggbranschen är i behov av att effektivisera byggprocessen och man ser BIM (Building Information Modelling) som en viktig möjliggörare för bättre kommunikation och minskade kostnader. BIM är en virtuell informationsmodell/informationsmodellering som beskriver konstruktionens alla ingående delar och deras egenskaper samt förhållandet mellan dessa. Ser man på infrastrukturprojekt, generellt och i Sverige och Australien, så är användandet av BIM idag relativt ovanligt. Vägen att introducera BIM är inte helt självklar och det krävs en del förändringar i projekten och dess organisationer. Bland annat att bör man omfördela resurser och arbete, samt vissa beslut, så att dessa kommer in tidigare i projekten. Dessutom behövs ny kompetens som kan bidra med kunnande om modellorienterad informationshantering. Och då man samlar olika discipliners projektering till en eller flera informationsmodeller så behöver dessa i grunden samordnas, också tekniskt, med bland annat kompatibla överföringsformat.

Syftet med denna SBUF studie är att via fallstudier undersöka hur man har använt sig av BIM i två infrastrukturprojekt, ett i Sverige och ett i Australien. Studien utförs som en del av ett examensarbete i ett samarbete mellan NCC Teknik och Hållbar utveckling och Chalmers tekniska högskola i Göteborg samt Sustainable Built Environment National Research Centre (SBEnrc) i Australien. Det australiensiska projektet utgörs av Moreton Bay Rail Link (MBRL) där man har använt sig av 3D/BIM modeller i byggandet av en järnvägsstation och det svenska utgörs av en etapp av Förbifart Stockholm. I MBRL drev arkitekten på att använda BIM och i det svenska projektet var detta ett krav från beställaren, Trafikverket.

Genom fallstudierna har flera områden av fördelar och utmaningar identifierades. Konstaterade nyttor är främst förbättrad kommunikation i projekteringsfasen och mot produktion, vilket underlättar samsyn i projektet, s.k. *clash controls*, som hittar fel och krockar innan dessa når produktionen, samt möjligheterna att kunna ta ut 2D ritningar direkt ur 3D modell. Man kan konstatera att förändring mot BIM behöver ett nytt tänk i process och organisation samt nya roller med ”modellorienterad” kompetens. Även om bägge projekt har visat goda resultat genom att använda sig av BIM så återstår ändå en viss skepsis mot användandet av tekniken. Det är därför viktigt att i projekt tidigt förankra arbetet med BIM, vad som skall göras, hur, samt vad som förväntas ut av det. Det är också viktigt att utveckla upphandling av projekt med BIM och att förtydliga dess nytta i projekt. Bägge projekt visar att IT-mognaden generellt, och BIM-mognaden specifikt, är ganska låg. Det är tydligt att utvecklingen mot BIM kräver en stark drivkraft. Både i Sverige och Australien, samt i flera andra länder, pågår nationella initiativ för att lyfta BIM i byggprojekt. I Sverige kräver Trafikverket, en offentlig beställare med ansvar för byggande, drift och underhåll av statliga vägar och järnvägar, BIM i alla sina projekt från och med 2015. Sådant krav finns inte i den australiensiska motsvarigheten, *Department of Infrastructure and Transport*, även om man här ser BIM som en naturlig del av byggande och förvaltande i en nära framtid.

SUMMARY

The construction industry is in need to streamline its processes and recognizes BIM (Building Information Modelling) as a facilitator for better communication and reduced costs. BIM is a virtual information model that describes the design, its including part, their characteristics and the relationship between them. The use of BIM in infrastructure projects is still however generally rather uncommon. The road to introduce BIM requires not only a technical changeover but also changes in organizations and competences. Projects need to reallocate resources and work activities, as well as some decisions earlier in the process. New skills are needed that can contribute with expertise on model-oriented information handling and management. Technically required advances include for example the ability to merge and coordinate different design areas information models and common exchange format.

The aim of this SBUF project is to examine the use of BIM in two infrastructure projects, one in Sweden and one in Australia. The study is conducted as a part of a diploma thesis in collaboration between NCC Engineering and Chalmers University of Technology in Gothenburg, and the Sustainable Built Environment National Research Centre (SBEnrc) in Australia. The Australian project, the Moreton Bay Rail Link (MBRL), have used 3D/BIM models in the construction of a railway station and the Swedish project, one phase of the Stockholm Bypass project, have used BIM in the construction of a new motorway link. The driving force to use BIM in the MBRL project was the architect and in the Swedish project BIM was a requirement from the client, The Swedish Transport Administration (Trafikverket).

Identified benefits from using BIM in both projects are primarily improved communication in the design phase and between design and production, facilitating understanding about the project, clash controlling – finding and handling errors and conflicts before they “reach” production – and being able to extract 2D drawings directly from 3D/BIM models. We can note that a change towards BIM requires new thinking regarding processes, organization and new roles including "model-oriented" skills. Although both projects have demonstrated good results using BIM so remains nevertheless certain skepticism about the technology. It is therefore important to establish the BIM work process firmly and early in projects – what is to be done, how, and what is expected out of it. It is also important to organize procurement with BIM and to communicate the expected gains. Both projects showed that the IT and BIM maturity level is rather low. It is clear that the realization of BIM requires a strong driving force. Both in Sweden and Australia, as well as in several other countries, national initiatives are underway to lift BIM. The Swedish Transport Administration (*Trafikverket*), a government agency responsible for the long-term planning of the transport system, requires the use of BIM in all their projects as from 2015. Such a requirement does not exist in the Australian Department of Infrastructure and Transport, although they see BIM as a natural part of the building and maintaining of infrastructure in the future.

CONTENTS

NOTATIONS

AIA – American Institute of Architects

BIM – Building Information Model or Building Information Modelling

CAD – Computer Aided Design

D&C – Design and Construct

ICT – Information and Communication Technology

IPD – Integrated Project Delivery

MBRL – Project: Moreton Bay Rail Link (Queensland Department of Transport and Main Roads, Australia)

QTMR – Queensland Transport and Main Roads, Australia

TMR – Department of Transport and Main Road, Australia

2D – Two dimensions: x and y

3D – Three dimensions: x, y and z

1 INTRODUCTION

1.1 Background

The common interest in the construction industry is making the building process more efficient. One solution is to invest more time and money in the earlier stages of the projects. Precise planning and designing the overall process in detail decrease the risk of making mistakes further on in the project. Another important step is to move away from the traditional 2D- and document-based way of working and instead introduce BIM models for delivering building projects. The use of BIM in the construction industry has increased during the last years (Linderoth, 2013), but has, however, only marginally affected the way we are working (the processes), which, more or less, still are the same. We are therefore yet to see the real productivity and quality gains and economic benefits of the change.

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, 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 Management, 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 the technology (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 of this study 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 study is part of the on-going research collaboration between Sustainable Built Environment National Research Centre (SBEnrc) in Australia and NCC Teknik och hållbar utveckling (THU) and Chalmers University (CTH) in Sweden. The study focuses 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. A cross-country comparative analysis was executed to detect and define similarities and dissimilarities between the countries.

The two projects chosen for the case study were (at the time) both on-going infrastructure projects – the Swedish project still in an early stage of the design process and the Australian in the production phase – where the uses of BIM were a central point in respective project planning.

1.3 Problem definition

The use of BIM in the house building industry is rapidly growing, but the use of BIM in infrastructure projects is still relatively low. There is a lack of knowledge, however, 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 and investigate how implementing new information and communication technology (ICT), such as BIM, affects infrastructural projects. Based on this, following main question and research questions have been defined:

Main question:
How does the implementation and use of new ICT, here: BIM, affect infrastructure projects during the design phase?

Follow-up questions:
What does the design process in the specific infrastructure projects look like?

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

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

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

2 THEORETICAL BACKGROUND

2.1 Design process

The design process is basically divided into five phases, (i) architectural program, (ii) schematic design, (iii) design development, (iv) construction documentation, and (v) construction. Most crucial decisions are made in the earlier stages of the design process.

In a large and complex project, especially, it is useful to practise collaborative design with BIM. 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 to the organisation is often forgotten. Chiu (2002) argues 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, for example, 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 dedicated design organisation has to exist.

2.2 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 and BIM 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) points out earlier studies that show how difficulties appear in projects-based industries of extracting, distributing and applying knowledge across both cultural and structural boundaries. This makes it more complex to cooperate when the knowledge is averse, situational and locally embedded. In regard to knowledge work, communication and interaction aided by ICT, such as BIM and 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, for example, contractors, clients and architects. The need for information and knowledge exchange is in all projects extensive. Recent developments include ways to increase information and knowledge exchange. For example, new working methods supported by concurrent design, extreme collaboration and the use of BIM. Basically, these different working methods purpose is to improve the interface between stakeholders involved.

Studies regarding ICT implementation have resulted in identification of key implementation drivers and difficulties (Vachara Peansupap & Walker, 2006). In the construction industry these are crucial when providing a strategic view of the implementation of ICT success. The studies also pointed out barriers that prevented adoption to ICT in the construction industry, for example low knowledge of ICT and insufficient investments. Few studies, however, examines the implementation constrains of ICT in the perspective of innovation diffusion at the organisation, work team and individual level (Vachara Peansupap & Walker, 2006).

The process to introduce new ICT to an organisation can be described as ICT diffusion. Unwillingness to participate in this process can emerge at several different levels: personal, organisational or at group level. In order to improve ICT diffusion, however, it is vital to gain a deeper understanding of the diffusion constrains and finding ways to overcome them.

2.3 Building information modelling (BIM)

A large amount of the communication in construction projects today is document- and 2D-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). Basically, engineer´s 2D drafting work was speeded up by electronic drawing boards. 3D modelling applications already existed at this time but were expensive and offered limited potentials to increase efficiency. In the 80s the technology developed and it became also more commonly to access a personal computer instead of mainframe computer systems. This made it possible for the CAD software developers and dealers to branch out in the construction industry, advancing towards a broader adaption of 3D modelling software systems during the 1990s. The technology has from then continued to develop beyond a geometrical representation in three dimensions (3D) to include designing “objects with contents”, or Building Information Models (BIM). The implementation of BIM within the construction industry has in the recent years increased significantly.

2.3.1 What is BIM?

When using BIM technology, one or several parts of a project are constructed digitally in a virtual model (Eastman, 2011). BIM provides great promises for improve analysis and control in a project, as well as boosting a concurrent way of working including multi-disciplinary design development. 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)

It is important to have a clear definition of what BIM is and why it is used. In addition to design 3D-models there are also models that include information regarding *time planning, financial management, calculations* and *simulations* (BIM Alliance, 2014). Sometimes confusing whether the acronym “BIM” means (noun) *Building Information Model* or (verb) *Building Information Modelling.* This report uses the definition (Eastman, 2011): “a modelling technology that embraces the process of communication, produce and analyse building models”.

Four criteria have to be fulfilled:

(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), being used throughout the whole project to save time, effort and money not only in designing and building but also for operation and maintenance.

2.3.2 Levels of BIM

When working with BIM it is useful to define different levels of BIM to clarify the concept (Building Information Management, 2011). One way is to identify and categorize different levels from the information contents and representation. Below figure illustrates the BIM maturity levels 0-3 acknowledging step-by-step impact that both data and process have on BIM. A brief summary of each BIM level is listed below the figure.

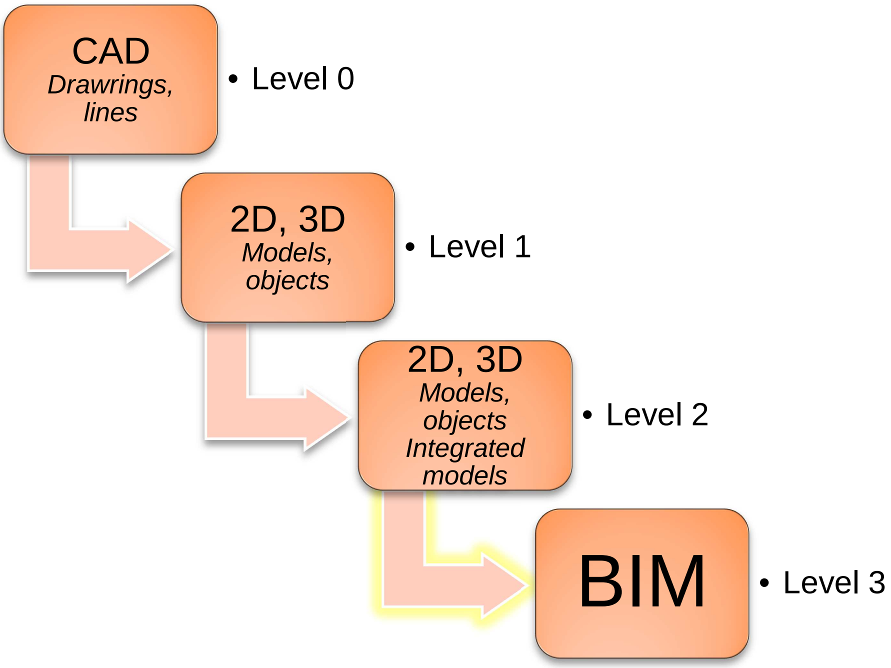

Figure 1 *Levels of BIM* (ArchiTECT-BIM, 2013)

Definitions of the different BIM maturity levels:

Level 0: This level contains unmanaged CAD, most likely 2D (both paper and electronic) (Building Information Management, 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). Typically 3D models for conceptual design during the early project stages and for visualisation of the finished project for presentation to the client, however not used collaboratively between project participants.

Level 2: 3D environment with attached data is managed with BIM tools and the detail lever is higher (Building Information Management, 2011). This requires production of 3D models by all key members of the design team.

Level 3: At this level the model has the capability to test the construction, perform various analyses including data from different designers.

2.3.3 BIM impact

Implementation of BIM in organisations has social impact on individuals, the organisation itself and the profession (Deutsch, 2011). By understanding how the social communication, culture and collaboration impacts on the firm the implementation of new technology such as 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?"

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.

Among design professionals the adoption of BIM is not widespread, even if an uptake of the new technology has happened rather quickly (Deutsch, 2011). In cases where the adoption has been successful it is typically due to human factors. In contrast, typical “human-factors” that would prevent technology adoption are incorrect attitudes and mind sets.

Advantages with BIM that have been acknowledged up to now can mainly be associated with the design phase (Linderoth, 2013) for example for detecting collisions, which later could cause problems and additional work, and for coordinating AEC work. More good examples are using visualisation for design feedback and to validate design requirements. Greatest positive impact of BIM can be found on the quality, cost and schedule of construction projects

2.4 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 ICT is motivated. Good project management systems have always been needed for clients to manage projects teams successfully. Equal importance comes from being able to create an efficient collaborative environment. One facilitator could come from using new ICT and BIM tools to support collaboration and exchange of information. This, however, requires all involved parties involved in the process to change the way they work and processes towards a more collaborative approach. When using 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.

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. 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 clear. As a result of this, difficulties often appear when adapting these new ICT systems to current practice, and vice versa. For example, 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. Certainly, 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.

2.5 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 characterized by key project stakeholders early assemble into an “integrated team” supported in teamwork by open and collaborative work processes and tools.

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. Communication is mainly digital using virtual models such as 3D and BIM. The IPD principles can be included into formal agreements to encourage, promote and support open sharing collaboration with risk sharing.

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, increasing the opportunities for a successful project.

The AIA, for example, works actively with other construction industry stakeholders and leaders and the public and private sector promoting the benefits to facilitate to transition towards a more collaborative approach in construction projects.

3 METHODOLOGY

This study is part of the on-going research collaboration between Sustainable Built Environment National Research Centre (SBEnrc) in Australia and NCC Teknik och hållbar utveckling (THU) and Chalmers University (CTH) in Sweden.

3.1 Process overview

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. A cross-country comparative analysis was used to investigate improved productivity through the use of BIM.

Carrying out the study (as a part of a master thesis work) the methodology was divided in seven steps as shown in *Figure 2 Methodology appliedFigure 2*. Initially, the objectives of the thesis were defined into a problem definition including some research questions. Work started out with a literature review to establish a theoretical framework, define some key terms and definitions, define and establish area of study as well as case studies. Interview questions were formed based on objectives of the study and conditions of the cases. Same questions were used in both (Australian and Swedish) cases. The interviews were carried through and additional information was gathered and analysed. Once compiled, the outcome of the reviews and case studies was discussed and is presented in a discussion chapter. Concluding remarks are presented in chapter 5 “Discussion and Conclusions”.

Figure 2 Methodology applied

3.2 Methods

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 study 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 construction project’s location, type and size. Since the aim of the report is to compare the use in Sweden and Australia, the projects naturally had to be located in these countries. Both projects are infrastructure projects in the earlier phases of the project using BIM as a form of communication in planning and design.

3.2.2 Qualitative data collection

Qualitative data collection has been carried out through interviews with people professionally connected to the two cases (construction projects). Interviewees were categorized into (i) client or client representative, (ii) designer, and (iii) contractor in order to provide different views to the questions.

The interviews in Australia were carried out with help from the research assistant Adriana Sanchez at *SBEnrc*, aided in contacting companies involved in the Australian infrastructure project and organized the meetings with the interviewees. The interviews in Sweden were carried out in a similar way with help from NCC.

3.2.3 Interview questions

The interviews followed an "in-depth semi-structured interview approach", which, according to (Gilmore & Carlson, 2007), 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. Basically, this approach helps to (i) cover a wider area of interest, (ii) identify and explore the key issues, and (iii) provide opportunity for further examining.

Basic information about the companies and their organisation were collected before interviewing. This information provided basic knowledge and enabled the refining of the interview questions. The interview 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) results from using BIM.

3.2.4 Interviewees

The interviewees were chosen from (i) having a key role within the infrastructure construction project (ii) having knowledge and experience of the use of BIM in the actual project, (iii) having access to relevant and correct information that could be used as basis for the case studies, and (iv) being willing to participate in an interview. *Table 1* categorizes interviewees and the companies they work for.

A total of ten persons were interviewed, five in Sweden and five in Australia. The interviews were held at respectively company office, and each interview took approximately one hour to conduct. All interviews were audiotaped with the interviewee´s permission.

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 study was analysed separately and thereafter a cross-country analysis was made. The information from the performed interviews was the main source for the analysis. The results from the case studies were compared with each other. First, the benefits and challenges by working with BIM were identified. Therefrom, the cultural differences between the countries were studied to see if they affected the process when working with BIM.

The main purpose of conducting a cross-county analysis was to study the similarities or dissimilarities between the countries. Both Australia and Sweden being countries with a rather low habitation in comparison to its size, their economies are relatively strong, the economic development is similar to each other, and both countries are monarchies with similar political climate.

4 Results from the Case Studies

4.1 Australia, Moreton Bay Rail Link

The first case study took place 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 early stage of a project, before commencing design work, it is essential to define and establish the project objectives. As commented by the architect, “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”. As a response to this, early in the design work, the architect produced a document “BIM framework”. This document, which later was included to the client agreement, defined what was expected from each consultant regarding models and/or drawings. It defined the purposes and uses of the models as well as how they would be produced and maintained. All of these aspects about working processes and BIM and 3D were agreed on before project start by all team members.

The Moreton Bay Rail Link contract initially required a delivery of 2D drawings, but the architects decided at an early stage that the complexity of the project required communication with 3D/BIM models in order to produce a successful end result. Because of cost reasons only one railway station was modelled in 3D. The design of that particular railway station was however similar to the others which made it possible to use it for promotion and information activities.

A *federated model* (assembled 3D model) was produced by the architect from 3D basis from architecture, hydraulics, electrical and structural designers. To be able to work with BIM in the project different software programs are used. A variety of designers' software programs were used: AutoCAD and Revit for 2D and 3D models, Navisworks to assemble models, collaboration, coordination, clash controls and for design reviews. Civil engineering design used the 12D model system. Additional "local" software programs used in the project are SPACE GASS and BlueView (to assembly models from different designers). Navisworks has been especially useful, the architect mentioned, to facilitate collaboration and to assemble multi-disciplinary information in an effective way. The clash control function made simplified the process off error finding not only locating the errors but also made it easier to handle them.

Use of 2D and 3D models on site

The *federated* 3D model was available for use for everyone on the building site. The surveyor on site received models which were handled via the 12D model system and the Terramodel system, which is a surveying tool that enables surveyors to set out the project coordinates. One practical approach of this was to link transports of material to the design model via the survey model system, Terramodel, and coordinates.

BlueView, an internal GPS-compatible communication tool was used at the construction site to access 2D drawings extracted from AutoCAD and 12D model system. Design progress and progress updates in all areas could be supervise on distance via laptop, tablet or similar. The GPS-function in BlueView helped to locate changes on-site. The system also allowed communication setup including for example taking photos, using FaceTime (videotelephony) and distribute documents. This system was widely used by the managers, for example, to get "quick answers" to questions and to introduce new staff to the site. Using tools as BlueView is a new experience for almost all staff, which demanded some change in work setup and performance. It was however an appreciated tool facilitating being involved in the work process, following the progress and to document files and events for later use.

Benefits

Both the project manager and the architect stated that the most outstanding benefit with the use of BIM are that many construction issues can be solved with clash detection before production. BIM also facilitated in the design work uncovering a variety of other "construction-related" issues that would later appear on site.

The level of collaboration in the project can be considered high. Different consultants produced models which later were put together in a common model, a *federated* model.

Much of the work took place at a project-common office in the vicinity of the site. Working closely was considered a great benefit facilitating coordination, communication and collaboration, saving valuable time and efforts for the project.

The Terramodel system made it possible to track the materials and trucks on site. This improved and facilitated for a lot of logistic aspects and preparations. Possibilities for communication improved which help solve minor and major issues or just communicate about the ongoing construction. FaceTime conversations were a new experience for most staff but, however appreciated especially for quicker problem-solving purposes.

Challenges

One of the biggest challenges of using BlueView is to organize the great amount of information channelled through the system – to access right and enough information at the right time. There were some problems in compatibility between information systems that occasionally challenged exchange of files. The project manager explained, however, that most challengers can be found in humans' behaviour and their attitude "No one is ever happy, it is always a problem". It is easier to find error or obstacles than try to comply with what resources that are available making the best of the situation.

To use the tool BlueView as efficient as possible it requires an understanding and of the system, including administration, and to handle great amount of information into models (BIM). Because of lack of time and resources, working with BIM was sometimes of lower priority. The BlueView system was however a great help in this process.

4.2 Sweden, the Stockholm Bypass

The Stockholm Bypass is one of Sweden's largest infrastructure projects. The project, which started in 2006 (TRV, 2014a), is a new route for the European highway (E4) past Stockholm. A new link west of Stockholm has been under investigation for several decades and a large number of different alternatives have been studied. To reduce the impact on sensitive natural and cultural environments, just over 18 km of the total of 21 km of the link are in tunnels. When the link opens for traffic it will be one of the longest road tunnels in the world. By 2035, the Swedish Transport Administration (Trafikverket) estimates that The Stockholm bypass will be used by approximately 140.000 vehicles per day.

It is estimated that the population in the Stockholm region is going to increase with 400 000 inhabitants in the following 20 years (TRV, 2014b). This increase of population 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

The head of major projects at Trafikverket decided at an early stage in the project that BIM should be used, although there were no detailed instructions about how and to what extent. The technical manager for the Stockholm Bypass and two more staff at Trafikverket saw the opportunity and started to sketch up how to implement BIM in the project. It ended up that the (consultants) contracts stated that BIM was not mandatory although 3D and BIM models were required for inspection. Trafikverket requested however that the consultants should be able to handle two new roles in the project, model coordinator and "model pilot" with knowledge and experience of BIM software to be used in order to support other project members in everyday work and to develop skills. This collaboration aimed beyond current project to include also future projects. Later development of the design work included to use 3D and BIM design in all areas. Some of the consultants had worked with 3D or BIM before in other projects and others were less experienced. None of the consultants complained about this development, though. The technical manager believed that all consults did not actually understand the situation and what was demanded from them. Thus, once the work started, some consultants had to learn new tools and this new way of working. The main difference from working traditionally with 2D was considered to be that you generated 2D drawings from the 3D model and that the work load was more focused at an earlier phase of the design process. It was also said that the "BIM process" required a closer collaboration then a traditional "2D-process".

Level of BIM

All consultants were required to deliver BIM models with a predefined level of detail, LOD 200 equivalent to that the model element is graphically represented within the BIM model as a generic system, object, or assembly with approximate properties such as quantities, size, shape, location, and orientation. Non-graphic information could also be attached to the model element. Linking between objects in different models was not possible. This information and information about contents of the BIM models were instead defined in the file information.

The use of BIM

Trafikverket developed at an early stage virtual reality models from 3D models to be used in design review. Some of the designers made 2D drawings directly from the VR-models, one example being sketching on the bridge structures. Both BIM/3D models and the later developed VR models were used to extract 2D and 3D views to discuss future solutions and to make decisions. They were considered a great help to explain the ideas of the future design. An elaborated 3D-model was produced to show the project in full – as planned to be. Model information contained for example facts about the ground conditions linked to certain areas.

Trafikverket and the consultants continued to supply the project with BIM models and gradually developed the working process into more collaborative “BIM processes” where the models as such also are used in a higher degree, for example, clash controls, reviews, specifications quantity take offs. Over time not only information was added to models but also removed as its purpose was gone. As-built models were fitted as requested by contract and delivered in appropriate file formats for exchange and documentation. As-built models were also used to facilitate operation and maintenance. Adding and subtracting information over time was generally no problem. There were however problem with linking of objects or group of objects within models when aggregated with other models as the linking often disappeared or was altered. This ended up in quite some extra work for the consultants and client.

Benefits

Several benefits from working with BIM were identified. The consultants benefitted most in the design phase and the contractor in the production phase. One of the benefits when working with BIM in this project was improved coordination, surely, but not proven, saving time and money. There were also noticeable effects on design errors as they were decreasing, and keeping the information up to date and coordination with other parts of the Stockholm Bypass project, setting the foundation for later and further use of BIM.

3D models were used to communicate with the public. This was especially useful when explaining complex design or the “full picture” of the project to the public as well as project participants. 3D and BIM models were also used for collision detection and for safety work, reducing errors before the production phase.

There were some difficulties in the project in communicating with BIM and 3D models. Most often this was due to unfamiliarity with the tools and working “3D” instead of “2D”. From the clients´ side the process of getting people used to work model-based started early in the project to continue into the phases of reviewing and approving consultants design work. Unfortunately, IT knowledge is still in general low and even working with basic viewers can meet resistance. In working with more advanced project review software, model coordinators and the, so called, “model pilots” aided other staff in handling the program and its functions. It seemed like the client, Trafikverket, overestimated their employee’s capabilities to handle and work with models.

Challenges

The greatest challenge for all project participants was basically to work object-oriented instead of with drawings. There were no standardised processes and work activities that could guide people through the project so this had to be tried out and established gradually, which of course have taken its cost in time and efforts. There were also some difficulties in exchanging data between different design and visualisation tools.

The project management was nevertheless satisfied with the model-based design delivered from the consultants. The consultants being the first to technically adopt working with BIM and thus understand and further develop its benefits in working processes.

Constraints in public tendering prohibit the client, Trafikverket, to set up certain conditions regarding BIM. For example, they cannot demand certain BIM or 3D tool or exchange format. Of course, being "software neutral" is important for a public client, even though it has some effects on not being able to plan and define specifics of information handling at an early stage. There are also some difficulties to see to that information and systems are compatible throughout the course of the project, especially considering larger and more complex project such as this lap of Stockholm Bypass. Therefore, from a "BIM process point of view" it is essential that collaboration works to that extent that all project partners can see to that their information handling is compatible to what other partners use, and to what the project requires. That could mean adapting to new systems, tools and ways of working. Present, Trafikverket, as a public client, are trying to find new ways – legal and practical – to include BIM in the tendering process – to being able to control the chain of information from initial idea and sketch to operation and maintenance.

When the project started is was decided it would be up to each consultants to decide which software programs and "local" formats to use in their design work. This led to that approximately 35 software programs were in use at one stage. Trafikverket made the compromise to allow any type of software for design but for information exchange using a common exchange format. This had some effect on models information contents as the "local" formats sometimes was not fully compatible with the exchange format. Defining a common exchange format had however the benefits that it was indeed common so that everyone knew what to plan for in regards to forthcoming information handling.

4.3 Cross-country analysis

At time of writing, the projects in the case studies are at different stages in the construction process. The project in Sweden, the Stockholm Bypass, is still being built and the project in Australia, the Moreton Bay Rail Link (MBRL), is in the production phase. The results from the Stockholm Bypass project interviews cover information about an "early stage implementation of BIM" covering all project stages. The results from the MBRL mainly contain information about the use of 3D models and BIM in the production phase. During the design process the architect in the MBRL project requested for a BIM framework, but was met with little enthusiasm from the project manager, mostly due to lack of time and resources and little knowledge about the financial aspects. In the Swedish project, however, the client, Trafikverket, had BIM as a requirement for the design work. Expected effects of implementing BIM were:

(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

Interviews in both projects confirmed use and “usefulness” regarding (i) and (ii): improved collaboration, clash controls and visualisations. Especially clash controlling – finding and handling problems before they occur on the building site – was thought to have greatest potential for saving time and money. One could speculate that finding and assessing design errors is more tangible than “improved collaboration”, which is why the effects of clash controlling are more noticeable. Also generating 2D drawings from 3D/BIM model (iii) was confirmed to save a lot of time and work.

As regards who is the driving force for BIM in a project there is a clear cultural difference between the two projects. In Australia, the role of the architect is significantly stronger than in Sweden. In the MBRL project it was the architect who delivered most of the BIM, especially for the railway stations. The influence from the architect as regards BIM was not as strong in the Swedish Stockholm Bypass project, not being the same driving force for BIM. Estimating the financial gains from using BIM were not possible at time of writing since both projects were still ongoing and no estimations had yet been carried out. One could however conclude from the interviews, in both projects, that the success rates were high in using BIM. One should note, however, that a direct comparison between the projects is difficult since they are in different stages of the construction process. Both projects showed that even though it was decided to use BIM they still were depending on people as driving force to see it through. It seems as the possibilities of reaching financial gains is not enough to perform the necessary changes in process and work. BIM is undoubtedly starting to take off, but maybe not as quickly as expected. In some countries, for example Australia, government and industry associations are being urged to help speed up the process. The UK Government has specified that all central government departments will be required to “adopt fully collaborative 3D BIM (in terms of BIM maturity, this is Level 2 BIM which means, among other things, that all project and asset information, documentation and data is worked on electronically and collaboratively) on their projects as a minimum by 2016”. This decision to make BIM part of its procurement policy has however met with some scepticism. Finland, being a pioneer in BIM, now requires the use of BIM for government procurement, and Sweden following these footsteps and also initiated concerted efforts to increase a nation-wide implementation of BIM. This led to the launch of the non-profit organisation OpenBIM (now BIM Alliance) in 2009 to establish BIM standards in Sweden. Public organisations such as the Swedish Transport Administration (Trafikverket) also mandated the use of BIM from 2015 ((Trafikverket, 2013)) as part of their nation-wide efficiency program (Albertsson, 2013). As part of their strategy, Trafikverket also developed legal guidelines on digital deliveries for construction works in collaboration with construction sector players via the Svenska Byggbranschens Utvecklingsfond (SBUF, Swedish National Construction Industry R&D Organisation) (SBBEnrc, 2014).

5 DISCUSSION AND CONCLUSIONS

The purpose of this study was to investigate the use of BIM in infrastructure projects.

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.

The people in the MBRL project in Australia were from an early stage very positive about BIM and the use of visualisations in the project. This presented high expectations to the study and gave an indication that they were aware of the benefits from working with BIM. The interviews showed however that the actual benefits from using BIM were not considered as high as expected. Contrary in Sweden, where people initially were more cautious about their expectations from BIM. Here, the interviews instead that people were more satisfied about the benefits of BIM, which were much higher than expected.

Development of new ways of working

As discussed earlier, when working with new technology, change is required to project success, protocols and practices (Jaradat *et al*, 2013). Both projects, the Moreton Bay Rail Link and the Stockholm Bypass, put a lot of effort work in adapting the work procedures to BIM. The client of the Stockholm Bypass project, Trafikverket, looked further towards coming projects and their main goal is to implement BIM in all of their future projects. A full implementation requiring new working procedures and guidelines. Working with new ICT such as BIM is complex and adapting to the new technology must be clearly managed with a high degree of collaboration and integration across project tasks. Using the BlueView tool was a great help in the MBRL project to handle the 3D/BIM models and to adapt to using the new technology. By using Blueview they could collaborate in a new way and 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 made the work on the construction site more efficient and made it possible to use models in a new way of work.

Development of new roles

As described earlier, Jaradat *et al* (2013) explains that new roles can be developed when professionals works closer in projects. Large digital systems can however 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 to include two new "BIM roles" – a "model coordinator" and a "model pilot" – to support 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 there were no new roles in the project.

Public organisations

Both projects included public organisations as client, Trafikverket in Sweden and the department of Transport and Main Roads (TMR) in Australia. The fact that both the organisations are public may influence how to carry out changes. 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)). One can argue that public organisations, with primary focus on people and communities interests and not short-term financial gains, are better equipped to invest in new ways, such as with BIM-technology, of working.

Benefits

The study can conclude following benefits from using 3D models 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 it was concluded that the main benefits from working with BIM was better coordination and also the ability to get 2D-drawings directly from the 3D/BIM model. Other benefits that were identified in this project were the understanding of how it all fits together when working with BIM through visualisation, collision controls and being able to improve working environment. When the right amount of information is selected from the model and can be interpreted correctly, the benefits will increase.

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 BIM software are not fully compatible as regards information exchange, which leads to a loss of information.

Another challenge is the working processes as the construction industry sometimes is rather conservative and working with 2D drawings sometimes still is preferred. Some people have little or no interest to learn and be willing to put effort in the learning process to be able to develop the use of BIM. The working procedures need to be standardized and it would be much useful to find one common way to communicate and present ideas and thoughts through a project.

Concluding answers to the follow-up questions stated in chapter 1.3:

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 so called Design and Construct contract was used, the entrepreneur is responsible for design and construction. Only one requirement has to be followed as regards BIM - and that is what level of BIM that were going to be used in the project: the architect creates a BIM framework, or road map, a document describing what is expecting from each consultant, what the end result will be and how they will deliver their design. In the MBRL project only one part of the project was however modelled in 3D, which was one of the railway stations. The Sweden project also applied a D&C contractual form with the entrepreneur as the responsible for design and construction which defined level of BIM used in the project. Tendering was partly based on 3D/BIM models.

At which level is BIM implemented in the different projects and how is it used?
When implementing new ICT such as BIM in a project it is important to decide what should be accomplished in the beginning of the project. Implementation of new technology is difficult and requires resources, time and money. The architect in the MBRL project had previous experience from BIM and was responsible for defining the level of BIM for the part of the project. For the part including the train station the level of

was level 2 – 3D models, integrated objects (see chapter 2.3.2 – BIM levels 0-3), level 1 for the rest of the project. The complete Stockholm Bypass project can be considered a level 2.

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 both projects were to find clashes before the construction work started. This facilitated planning and carrying out of working activities which saved a lot of time and effort. Using 3D models to create understanding about the project and its work processes was very useful. The Stockholm Bypass project made great efforts in adapting its working processes to BIM and made continuous improvements as the project was carried out. Not only Trafikverket, but also its consultants, are today quite aware about the BIM process. The Australian project did not make the same investment in developing its processes and made therefore not so much progress during project time.

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7 APPENDIX

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