BIM in Project Management

- A forecasting cross-case study examining how BIM effects the project management in large and complex construction projects. The study comprises two hospital projects; one in Australia and the other one in Sweden

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Abstract

BIM in Project Management
Bachelor thesis
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The construction industry is known to hold a quite low innovation level compared to many other industries. Along with the technical development, Building Information Modelling (BIM) has entered the industry in some of today's large and complex construction projects. BIM is an intelligent 3D-model based process used for creating and managing building projects. The purpose of this bachelor thesis is to find how BIM is applied on some of today's most complex construction projects, what the effects are on the project management and what can be done to increase the benefits from this technology. The thesis focuses on two BIM-projects, Nya Karolinska Solna (NKS) in Sweden and new Royal Adelaide Hospital (NRAH) in Australia.

In total seven interviews were conducted; one of the Design Managers from each project, the BIM managers and three BIM experts. It was concluded that both projects are to deliver a BIM model with the information and attributes linked to the content in the model. The model will be used in the Facility Management of the hospitals. Also the BIM-model is used for estimating during the procurement process. Personal and data analyses, such as clash controls, are conducted based on the model. Furthermore the progress of the project is followed via the BIM-model on the project platforms, which become a central communication base for wide understanding in the project. The main conclusion is that the implementation of BIM benefits the projects time and cost management. Even if BIM also requires an investment of time and money the interviewees are certain that the project benefits from BIM over the buildings lifecycle. The industry needs more time to develop tools and understanding to fully see the benefits on all levels and disciplines.

Keywords: BIM, Project Management, Design, Hospital, Construction industry, NKS, NRAH, Sweden, Australia

Sammanfattning

BIM i Projektledning
Kandidatuppsats
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Examinator: Anders Robertsson

Byggbranschen är känd för att ha en relativt låg innovationsnivå jämfört med många andra branscher. Den tekniska utvecklingen har gjort att Building Information Modeling (BIM) introducerats i några av stora och komplexa byggprojekt. BIM är en intelligent 3D-modellbaserad process som används för att planera och hantera byggprojekt. Syftet med denna kandidatuppsats är att undersöka hur BIM appliceras på några av dagens mest komplexa byggprojekt, vilka effekterna på projektledningen blir och hur vi framöver kan dra ännu mer nytta av denna process. Uppsatsen studerar två BIM-projekt, Nya Karolinska Solna (NKS) i Sverige och det nya Royal Adelaide Hospital (NRAH) i Australien.

Sammanlagt genomfördes sju intervjuer, med en projekteringsledare samt en BIM-chef från varje projekt samt med tre BIM experter. Studien visar att liknande krav ställs på projekten, man ska leverera en BIM-modell med information och egenskaper om objekten kopplat till modellen. Modellen skall senare användas i förvaltningen av sjukhusen. BIM-modellen används för att mängda i upphandlingen. Den används även för att utföra datoriserade och personliga analyser inklusive kollisions-kontroller. Intressenter följer utvecklingen av projektet via BIM-modellen på projektens centrala plattform som är en bas för kommunikation och information inom projektet. Tillämpandet av BIM främjar projektets tid- och kostnadsprocesser. Även om BIM kräver en investering av både tid och pengar i planerings och design fasen så är de intervjuade överens om att man det blir lönsamt över byggnadens hela livscykel. Byggindustrin behöver dock tid för att ytterligare utveckla verktyg och förståelse för att tillgodogöra sig fördelarna med BIM.

Nyckelord: BIM, Projektledning, Design, Sjukhus, Byggindustrin, NKS, NRAH, Sverige, Australien

Foreword

This bachelor thesis is the final part of the author's education at Lunds University of Technology and the school of engineering and comprises 30 credits. The work began in January 2013 and was completed in June 2013.

The idea to this rapport first came during my internship at White Tengbom Team in 2012 when they were designing the New Karolinska Hospital in Stockholm. I had studied BIM but had never seen the practical use of it in a construction project.

While studying abroad at the University of New South Wales in Sydney I met one Design manager from Hansen Yuncken who held a lecture about the design management in Australian hospital projects. He introduced me to the New Royal Adelaide Hospital that was also a BIM project.

When I later started planning my thesis I saw a way for this to nicely go together, my interest in project management with the interest in BIM. I wanted to find out how this new technology was implemented and effected the project management of the two large and complex projects.

In the title of my thesis I have two words with definitions that vary, BIM and Project management. BIM is a relatively new technology that is applied differently and to different extent in projects, therefore it also gets described differently. Project management in large and complex projects occurs on all levels, it exists both on an overall level and within each part of the project. I aim to make clear how I define these words in this context.

This thesis would not have been possible without the help of all the interviewees, taking the time and for so openly sharing their experiences with me. I am very grateful for this and hope that they find the report interesting. I would also like to thank my supervisors Martin Hooper and Håkan Fjällström as well as my examiner Anders Robertson for all sharing their valuable experiences and knowledge with me to produce an accurate report.

Least but not last I would like to thank my dad Thomas Rydén and my boyfriend Dave Bradley for assisting me and being such a great support while completing this thesis.

Helsingborg, June 2013
Jenny Rydén

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Notations

BIM	Building Information Modelling
CAD	Computer Aided Design
VDC	Virtual Design and Construction
IFC	Industry Foundation Classes
NKS	Nya Karolinska Solna Sjukhus (The New Karolinska Solna Hospital)
NRAH	the New Royal Adelaide Hospital
MEP	Mechanical, Electrical and Pluming
FM	Facility Management
QFM	Quality Facility Management
KPI	Key Performance Index
PPP	Public Private Partnership
2D	Two dimension, x and y
3D	Three dimensions, x, y and z
4D	A 3D model linked with a time plan
5D	A 4D model linked with a cost plan
6D	A 5D model linked with a life cycle plan

1. Introduction

In this chapter the background of the thesis will be presented to give you an idea of why this study is made. Later the purpose and aim, delimitation and disposition of the bachelor thesis will be described. The two case study projects will be presented together with the seven interviewees.

1.1 Background

1.1.1 The construction industry

1.1.1.1 Sweden

The construction industry in Sweden is an important part in the country's growth, development and prosperity. In 2010 the construction industry in Sweden employed 305 000 people which is 6,7 per cent of Sweden's working force. This includes people working in construction of buildings, construction of infrastructure and specialised installation and work in these two. The investments in the industry came to 266 billion Swedish kronor (43,2 billion AUD), 8 per cent of the total GDP (Sveriges Byggindustrier, 2011).

The innovation level of the construction industry is known to be relatively low compared to other industries. In a report Statskontoret made in 2009 called "Skärpning gubbar" they outline that the industry players are aware of the industry's innovation needs and lists some of the reasons for the problem:

- The slow tendency of change, the unclear demands for what should change and the low demands for it.
- The incentives to increased efficiency, competence and development are low in the building firms. (Statskontoret, 2009, pg.97)

1.1.1.2 Australia

The construction industry plays a significant role in the Australian economy and society. In 2010 the construction industry's share of the total production of goods and services in the Australian economy was 7.7 per cent. The total production of the measured by industry gross value was 102 billion AUD (635 billion SEK). In 2010 9 per cent of Australia's employed was in construction (ABS, 2012).

Reports on the industry have indicated that although innovation occurs the ratio of innovation for the industry is not as high as in many other industry sectors. The Australian Bureau of Statistics (ABS) conducted a survey of innovation in Australian industries for the period 2009 to 2010 and found that the construction industry, at 30.9 per cent, had one of the lowest proportions of innovation businesses. Businesses in construction were also the most likely

to cite lack of skilled persons within the labour market as a barrier to innovation (ABS, 2012).

1.1.1.3 Problem

Innovation will make the industry more productive. The productivity growth has been historically low in the Swedish construction sector (Statskontoret, 2009 pg.183). The industry is improving and there are a lot of investments to improve the efficiency particularly in large projects.

In Australia a report for Master Builders were published by the independent economics. This showed that the productivity in the construction industry in Australia has strengthened considerably the nine years from 2003 to 2010 (Independent economics, 2012).

The construction industry is one of our most important and complex industries in the world and therefore it has a constant demand of renewing itself and its processes. Factors that impact the industry include globalization of the business environment, demographic change, environmental sustainability and climate change, new materials and technologies, information and communication technologies and governance and regulation (D.S. Thorpe, N. Ryan, 2004).

Productivity is a relevant measurement of the efficiency of the production. One gets an idea of the productivity in an industry by dividing the production value on the amount of working hours. The higher value per work hour the more productive is the industry.
Two factors that drive the development of productivity in any sector is:

- Introducing of new and more advanced technology that makes the work more efficiently.
- The labours competence increases through education and experience. (Ekonomifakta, 2013)

1.1.2 Project Management

Today's large construction project are getting more and more complex which results in more complex processes in the project management. This applies both to the overall project management and to the management of the sub-parts of the project.

One of the most advanced buildings one can construct is a hospital. With all the development and new findings within the healthcare industry it is difficult to plan a hospital that will function today and in the next coming future.

This puts a lot of pressure on the different processes in the project management, therefore new tools and ways of working needs to be developed and implemented to stimulate this evolution.

The construction industry is a project-based industry. A construction project is difficult to compare to any other products since the processes for producing a large complex building cannot function or be as systemised in the same extent as in the manufacturing industry. There are some repetitions on every project though the complexity and uniqueness is still so great that the processes have to be customized and developed for each separate project.

1.1.3 BIM

BIM, Building Information Modelling, BIM is the result of the increased level of collaboration amongst researchers, software developers and industry practitioners in the last decades. It is now recognised as an emerging technological and procedural shift within the architect, engineering and construction (AEC) industry. BIM is not only considered as a way to make a profound impact on these professions but is also regarded as an approach to assist the industry to develop new ways of thinking and practice. (Wong, J. Yang, J. 2010)

BIM is transforming the world of design and construct, leading to higher efficient, cost-effective and timely construction projects. BIM is a digital representation of a facility's physical and functional characteristics, estimators, fabricators, contractors and suppliers can share this digital information to estimate waste and redundancy, control costs, and abbreviate construction timetables. This can assist project managers in their project management processes on all levels (Asset Works, 2012).

1.2 Purpose & aim

The purpose of this bachelor thesis is to find how BIM is applied on some of today's most complex construction projects, how it effect the project management and what can be done to increase the benefits from this process.

- How does the implication of BIM benefit the project management processes in these projects?
- What are the key benefits and challenges with BIM?
- Is there any difference in how BIM is applied in the two projects? If so, why is that?
- What are the forecast of BIM in large complex construction projects in the future?

1.3 Delimitations

In this thesis the author has chosen to focus on two large complex construction projects rather than small-scale projects. This because BIM is still quite new in the construction industry and therefore implementing it demands great investments in education and technology, something that one in small-scale projects often do not have the capability to do.

Because of the case study projects large size and of its complexity, the overall project manager who overlooks the projects over all processes does not get in contact with BIM. It is the Design Manager, the manager responsible for the project management in design who handles and sees the effects of BIM. Therefore when the author talk about the "project management" in this thesis it is the project management of the design that the author is writing about, which is a sub-part of the overall project management.

The author has chosen to focus on the Swedish and the Australian industry since these are the two industries that the author herself has experience of. Also it shows a global perspective because they are geographically on different sides of our globe.

1.4 Disposition

Chapter 2 – Method
Chapter 3 – BIM
Chapter 4 - Construction Project Management
Chapter 5 – Results
Chapter 6 – Analysis & Discussion
Chapter 7 – Conclusion
Chapter 8 - References

1.5 The Case study projects and interviewees

1.5.1 NKS

Image 1. NKS Head entrance, White Tengbom team

Data	
Construction contract:	14.5 billion SEK (2.36 billion AUD)
Area:	320 000 m^2
Start:	summer 2010
Completing:	autumn 2017
The Client:	The Stockholm County Council via Swedish Hospital Partners (Skanska and Innisfree)
Builder:	Skanska
Architect:	White Tengbom Team
Project management:	Skanska Healthcare
Health planning:	The NSK Administration
Facility management:	Swedish Hospital Partners (for 30 years) via Coor
Environmental:	ISO 14001
	LEED Gold certificate
	Miljöbyggnad
Contract:	The worlds largest PPP

The New Karolinska Hospital is the first university hospital that is planed in Sweden in over 40 years, the largest project ever for the Stockholm's country council as well as for Skanska and Sweden's first PPP hospital (Stockholms läns landsting, 2011).

NKS is a BIM project with the aim to become the world's leader in environmentally friendly applications to a world-class university hospital. It will be designed with the "Patient first" healthcare approach. This will be accomplished through a design where the patients have their own rooms, on multi-expert and multidisciplinary wards. This approach will except for making patients feel comfortable and curative, also prevent bacteria's from spreading.

The construction of the NKS is one of the largest building constructions in Europe. Five new buildings are in construction each between nine and eleven stories high. A research and technology building will be integrated into the hospital complex laboratories. This will result in a new ultra-modern university hospital for both specialized and highly specialized healthcare, research and education (Skanska, 2012).

Image 2. NKS areal, White Tengbom team

1.5.1.1 Interviewees

Peter Sundström, BIM manager at Skanska Healthcare. Peter has previous experience of BIM from working as a consultant at the project management department at Tyréns. In NKS his responsibilities are as the design manager for one of the hospital phases and since august 2012 he is also the BIM-manager at Skanska Healthcare.

Ulf Persson, Design manager at Skanska Healthcare. Ulf has many years of experience as a design manager and has, before working at NKS, applied digital visual tools in intelligent and non-intelligent ways. Ulf is overall responsible for the design in NKS.

1.5.2 NRAH

Image 3. NRAH Plaza entry, South Australia Health Partnership

Data

Location:	Adelaide, SA, Australia
Construction contract:	1.85 billion AUD (11.39 billion SEK)
Area:	251 000 m^2
Start:	June 2011
Completing:	2016
The Client:	Government of South Australia via SA Health Partnership
Builder:	HYLC, a joint venture between Hansen Yuncken and Leighton Contractors
Architect:	STHDI
Health planner:	Silver Thomas Hanley
Structural Engineers:	W&G /KBR
Services Engineers:	Bestec/ LCI
Facility management:	Spotless (for 35 years)
Project management:	HYLC
Quantity Surveying:	Rider Levett Bucknall
Environmental:	4 Green stars
Contract:	PPP

The new Royal Adelaide Hospital will be South Australia's greenest hospital. The new hospital will replace the existing Royal Adelaide Hospital that opened in 1840.

The NRAH will remain a major teaching hospital and will also be co-located with the new South Australian Health and Medical Research Institute, making the health precinct the hub of medical research in the State. The hospital is planned with focus on the patient care and will hold leading edge research, healing environment, advanced technology and high quality healthcare. A healing environment incorporates the use of gardens, water features, natural light, artwork and views in the design at the same time providing quit and privacy (SA Health 2012).

The new hospital will be delivered as a BIM-project, contracted as a PPP, financed by the State Government and designed, built and maintained by a private operator under a 35-year contract. The Facility will attract some 6,000 staff, treat over 400,000 outpatients per year and will provide overnight care to approximately 85,000 inpatient admissions per year (SA Health 2012).

Image 4. Areal NRAH, South Australia Health Partnership

1.5.2.1 Interviewees

Chris Penn, BIM manager at HYLC. Chris's history with BIM runs back to before it was even called BIM. He has been working with the first object-based systems. Since then he has worked in a lot of projects in the UK implementing BIM, most recent as a consultant for Scott Wilson as Group IPD BIM Director. He previously has worked on the London & Barts for Skanska and North Staffordshire Hospital for LOR.

Andrew Hallworth, Design Manager at HYLC. Andrew was previously working for Skanska in the UK as one of the design managers at the London Bath Hospital. In the NRAH he is now one of six design managers, responsible for the clinical side including interiors etc.

1.5.3 Third part

Gunilla Qvarnström, owner and CEO of projTools AB. Gunilla has been working with BIM since 2008. Her company is creating BIM tools and is at the moment developing a Revit platform. She was involved in NKS putting up the relevant processes, doing investigations and developing tools.

Martin Hooper, Architect, energy consult and BIM PhD at Lunds University. Martin has a great experience in BIM and has been completing a number of researches about the topic.

Mikael Kastell, owner and CEO of Kastell Consultants. Mikael has experience of BIM since 1998 including 10 years in Norway working with offshore projects. Mikael is currently the BIM coordinator for PEAB in building the mall of Scandinavia.

1.6 Definitions

Stakeholder
A Stakeholder is a person, group or organisation that has interest or concern in an organisation. This because choices the organisation makes affects them. The stakeholders in these case studies are the client, project manager, architect, discipline leaders, contractors and subcontractors.

Disciplines
A discipline means a branch of knowledge. In this rapport the different disciplines included in the project management of the design is the architect, the engineers and the installations.

Traditional Project
When comparing BIM-projects to traditional projects, a traditional project is one without any 3D modelling. Everyone is working only with 2D drawings.

IBIM
IBIM is a process of generating and managing building data over a buildings entire life cycle. If the data gets properly updated, organised and put in the right format, this can be used to deliver productivity and savings.

2 Method

This chapter presents the method that has been employed in this bachelor thesis. It will also describe how the collection and analyzes of data was conducted.

2.1 Deductive/ Inductive

The investigation in this bachelor thesis has been carried out on an inductive approach. This means that the data has been collected without beforehand formulating hypotheses. Based on the purpose and aim for this thesis data has been collected, analysed and compared to establish theory regarding concerned topics (Trochim, William M.K., 2006).

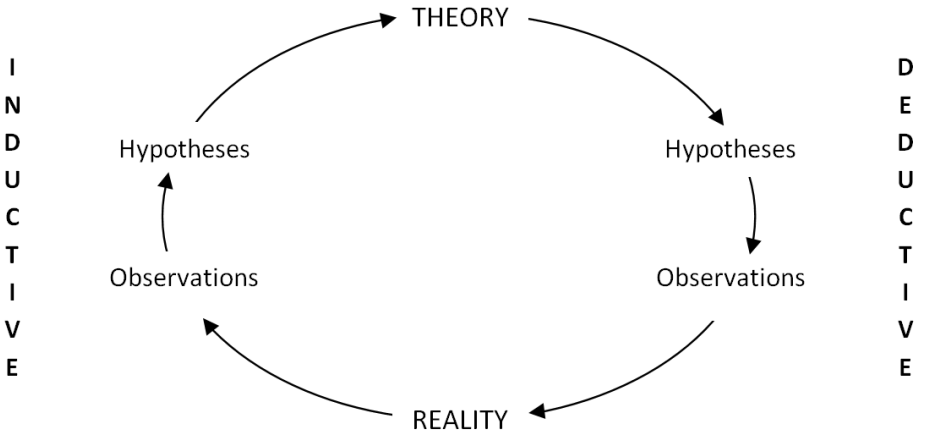

Image 5. Eriksson & wiedersheim-Paul, 1997

2.2 Quantitative/ Qualitative

Since this thesis is a cross case study, it is a qualitative study where a large amount of information is collected from two single sources. The purpose is to indentify and explore insufficiently known properties. The idea is to discover something that cannot be established in advance and acquire a deeper understanding of a subject. (Holme, I. M. Solvang, B. K. 1997).

2.3 Literature review

A literature review was performed in order to attain a comprehensible understanding of the main subjects relevant to this bachelor thesis; project management, BIM, the NKS and the NRAH. This made it possible to hold rewarding interviews. A research about how to structure a thesis was also performed.

2.4 Validity and Reliability

To keep a high validity the interview questions where formulated according to the purpose and aim of the thesis, these had two orientations, one for project managers and one for BIM-managers. This because project managers have a more overall view of the technology and a more detailed one of the project management processes. For the BIM managers the opposite applies. Only the people with relevant knowledge were chosen and interviewed.

Since it is difficult to achieve a high reliability in qualitative studies an additional focus was put on this. All the interviews were performed over telephone and recorded. The interviewees with different positions had to answer the same questions to reassure the information even if their answers were of different detail.

2.5 Method critics

I think the interviewees gave a very accurate and diverse view of the effects BIM has in the project management. They are all very experienced in the industry even if they have different experience of management and of BIM. One could have made a quantitative study and included more projects; possibly even designers not only design managers, to get an even wider overview of BIM's effects. It might have been better to interview people from the NRAH project later in the year since they just have started building on site, which means that they had only seen some of the effects of BIM in that project yet.

Since all the interviews where made over the phone it is difficult to say what could have been better with other interview techniques such as face to face or via e-mail. I believe that when answering questions via email the interviewees would have been able to stick to the question and to be more specific and detailed with their answers since they would have been able to edit it till they were satisfied. On the other hand I do not think that this would have been possible to do because it requires a lot more time from the interviewees. Time is, as I explain in this report, something extremely valuable in the projects that my interviewees are currently in the middle of. Therefore I also find it difficult to see how it would have been possible to do these interviews in person, face to face. It would have required more planning together with the interviewees, less flexibility with late time changes and transportation for me. Of course it would have been better for my research though I do not believe that it would have changed the results much. The positive with interviews over the phone was that I was able to adjust the questions to the different people and follow the conversation. This kept a relaxed atmosphere so that the interviewee could take her or his time to think about the answers. Some people gave quite strait

answers while some got sidetracked a lot. These sidetracks were not necessarily bad; it resulted in wider background knowledge for me as a researcher, which in the end resulted in a better report.

The literature research is quite small because of the focus on the interviews.

3 BIM

The purpose of this chapter is to introduce the reader to BIM and how it is viewed in this bachelor thesis. Furthermore, technical aspects of BIM and how the maturity regarding its use can be classified, is described.

3.1 Introduction to BIM

"The easiest way to explain that is before we used to draw lines on paper. Then we drew lines in computers and now we put information about the products in to the computer. Our 3D model not only represents the physical structure of the building but all the intelligence of the component parts that goes in to that structure.." (Scott, M. 2012).

Building Information Modelling is an intelligent model based process that is used for creating and managing building projects. The possible benefits are to run projects faster, more economically and with less environmental impact. In this intelligent model it is possible to design, visualise, simulate and collaborate the rich information in the intelligent model to inform better decision-making and break down the barriers to better business (Autodesk, 2013). This, since BIM allows all stakeholders to access the same information at the same time through interoperability between technology platforms (buildingSMART, 2012).

The process, Building Information Modelling, starts with modelling and using one or a couple of digital building models in the construction process. These models include other information as well (sometimes called VDC) than the geometric, this can be information about time scheduling, budgeting, calculations and simulations. The concept includes three parts:

- **The product** - the planned building
- **The organisation** - who will plan, construct and manage the facilities
- **The process** - that the organisation will follow during the process (OpenBIM, 2012)

BIM allows the testing of a digital prototype in advance of its physical realization, and because of this enables delivering greater cost certainty, eliminating error, improving program duration and reducing risk (Northumbria University, Ryder, 2012).

3.2 Technical aspect of BIM

3.2.1 Libraries

The key to BIM is the contents in the model containing attributes about the

content itself such as informational, material, performance and sustainability properties. These can be developed and distributed from the suppliers of the products or materials. The idea is to create the content once and reuse it many times. Unfortunately very few suppliers can assist with content in the right format and size yet, these therefore has to be drawn up by the designers on each project. National Libraries with contents exist to some degree and will keep being developed for the construction industry, enabling construction professionals to locate and download generic and proprietary BIM objects (NBS, 2012).

3.2.2 Education

Just like an onion has BIM many layers. The basic technicality with BIM is that it is software that enables 3D modelling and information management. Extensive use of the software eventually leads to a more complete understanding of the technical core. This is where the experience and practice with the software play an important part. It is important for the users to come to the understanding that there is a lot more to BIM than the technical core (WSP, 2013).

3.3 BIM Levels

2D - 2 dimensions (flat)
3D - 3 dimensions e.g. width, length and height.
4D - Adding the aspect of **Time** to a project (phasing/sequencing)
5D - Adding the aspect of **Cost** to a project (cost estimating)
6D - The aspect of **Life Cycle Management** (owner/FM)

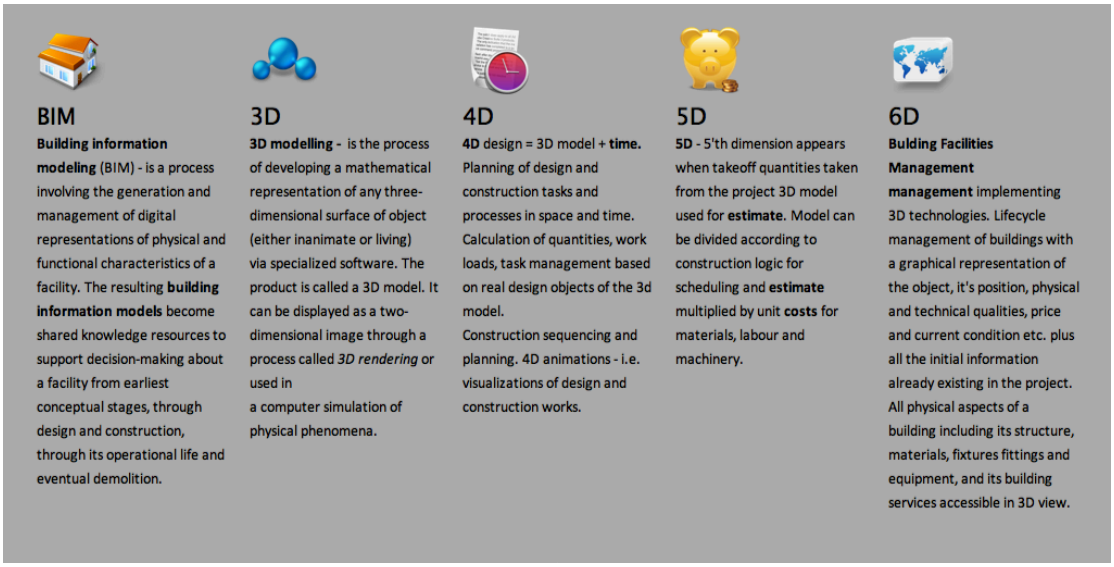

Image 6. BIM levels, www.ibimsolutions.com

3.4 Use and benefits of BIM

A study made by The Computer Integrated Construction Research Program (CIC) at Pennsylvania State University about BIM execution planning, identified the following uses of BIM.

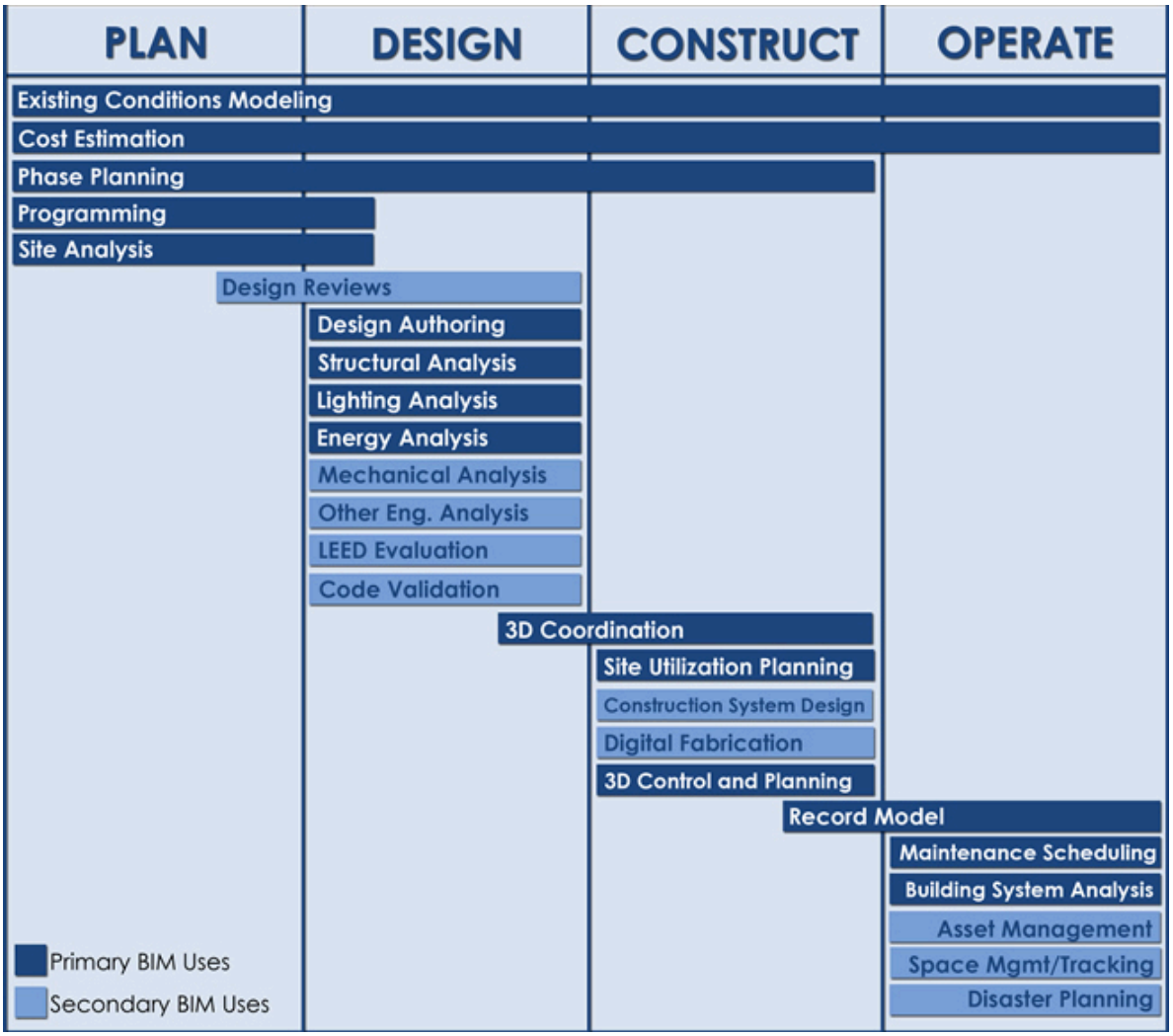

Image 7. Use of BIM in the different project phases, http://www.bim.psu.edu/uses/

3.4.1 Plan

Existing Condition Modelling

A process where the project team develops a 3D model of the existing conditions on site, once the model is constructed it can be queried for information.

Potential value:

- Enhances the efficiency and accuracy of existing conditions documentation
- Provides documentation of environment for future uses
- Aids in future modelling and 3D design coordination

- Provides an accurate representation of work that has been put into place
- Real-time quantity verification for accounting purposes
- Provides detailed layout information
- Pre-Disaster planning
- Post-Disaster record
- Use for visualization purposes
  (Messner, 2011)

Cost Estimation

A process in which BIM can be used to assist in the generation of accurate quantity take-offs and cost estimates throughout the lifecycle of a project. This process allows the project team to see the cost effects of their changes, during all phases of the project.

Potential Value:

- Precisely quantify modelled materials
- Quickly generate quantities to assist in the decision making process
- Generate more cost estimates at a faster rate
- Better visual representation of project and construction elements that must be estimated
- Provide cost information to the owner during the early decision making phase of design and throughout the lifecycle, including changes during construction
- Saves estimator's time by reducing quantity take-off time
- Allows estimator's to focus on more value adding activities in estimating such as: identifying construction assemblies, generating pricing and factoring risks, which are essential for high quality estimates
- Added to a construction schedule (such as a 4D Model), a BIM developed cost estimate can help track budgets throughout construction
- Easier exploration of different design options and concepts within the owner's budget
- Quickly determine costs of specific objects
- Easier to strain new estimators through this highly visual process

(Messner, 2011)

Phase Planning

A process in which a 4D model is utilized to effectively plan the phased occupancy in a renovation, retrofit, addition, or to show the construction sequence and space requirements on a building site.

Potential Value:

- Better understanding of the phasing schedule by the owner and project participants and showing the critical path of the project
- Dynamic phasing plans of occupancy offering multiple options and solutions to space conflicts
- Integrate planning of human, equipment and material resources with the BIM model to better schedule and cost estimate the project
- Space and workspace conflicts identified and resolved ahead of the construction process
- Marketing purposes and publicity
- Identification of schedule, sequencing or phasing issues
- More readily constructible, operable and maintainable project
- Monitor procurement status of project materials
- Increased productivity and decreased waste on job sites
- Conveying the spatial complexities of the project, planning information, and support conducting additional analyses

(Messner, 2011)

Programming

A process in which a spatial program is used to efficiently and accurately assess design performance in regard to spatial requirements.

Potential Value:

- Efficient and accurate assessment of design performance in regard to spatial requirements by the owner.
  (Messner, 2011)

Site Analysis

A process in which BIM tools are used to evaluate properties in a given area to determine the most optimal site location for a project. The site data collected is used to first select the site and then position the building based on other criteria.

Potential Value:

- Use calculated decision making to determine if potential sites meet the required criteria according to project requirements, technical factors, and financial factors
- Decrease costs of utility demand and demolition
- Increase energy efficiency
- Minimize risk of hazardous material
- Maximize return on investment

(Messner, 2011)

Design Reviews
A process in which stakeholders view a 3D model and provide their feedbacks to validate multiple design aspects. These aspects include evaluating meeting the program, previewing space aesthetics and layout in a virtual environment, and setting criteria such as layout, sightlines, lighting, security, ergonomics, acoustics, textures and colors, etc.

Potential Value:
- Eliminate costly and timely traditional construction mock-ups
- Different design options and alternatives may be easily modeled and changed in real-time during design review base on end users and/or owner feedbacks
- Create shorter and more efficient design and design review process
- Evaluate effectiveness of design in meeting building program criteria and owner's needs
- Enhance the health, safety and welfare performance of their projects (For instance, BIM can be used to analyze and compare fire-rated egress enclosures, automatic sprinkler system designs, and alternate stair layouts)
- Easily communicate the design to the owner, construction team and end users
- Get instant feedbacks on meeting program requirements, owner's needs and building or space aesthetics
- Greatly increase coordination and communication between different parties. More likely to generate better decisions for design.

(Messner, 2011)

3.4.2 Design

Design Authoring
A process in which 3D software is used to develop a Building Information Model based on criteria that is important to the translation of the building's design. Authoring tools create models while audit and analysis tools study or add to the richness of information in a model. Design authoring tools are a first step towards BIM and the key is connecting the 3D model with a powerful database of properties, quantities, means and methods, costs and schedules.

Potential Value:
- Transparency of design for all stakeholders
- Better control and quality control of design, cost and schedule

- Powerful design visualization
- True collaboration between project stakeholders and BIM users
- Improved quality control and assurance

(Messner, 2011)

Engineering Analysis
(Structural, Lightning, Energy, Mechanical, Other)
A process in which intelligent modelling software uses the BIM model to determine the most effective engineering method based on design specifications. Development of this information is the basis for what will be passed on to the owner and/or operator for use in the building's systems (i.e. energy analysis, structural analysis, emergency evacuation planning, etc.). These analysis tools and performance simulations can significantly improve the design of the facility and its energy consumption during its lifecycle in the future.

Potential Value:

- Automating analysis and saving time and cost
- Analysis tools are less costly than BIM authoring tools, easier to learn and implement and less disruptive to established workflow
- Improve specialized expertise and services offered by the design firm
- Achieve optimum, energy-efficient design solution by applying various rigorous analyses
- Faster return on investment with applying audit and analysis tools for engineering analyses
- Improve the quality and reduce the cycle time of the design analyses (Messner, 2011)

Sustainable Analysis (LEED Evaluation)
A process in which a BIM project is evaluated based on LEED or other sustainable criteria. This process should occur during all stages of a facilities life including planning, design, construction, and operation. Energy simulations, calculations, and documentations can be performed within an integrative environment when responsibilities are well defined and clearly shared.

Potential Value:

- Facilitates interaction, collaboration and coordination of team members early in the project process are considered to be favourable to sustainable projects.
- Enables early and reliable evaluation of design alternatives.
- Availability of critical information early helps problem resolution efficiently in terms of cost premium and schedule conflicts.

- Shortens the actual design process by the help of early-facilitated design decisions. Shorter design process is cost effective and provides more time for other projects.
- Leads to delivery better project quality.
- Reduces documentation load after design and accelerates certification because concurrently prepared calculations can be used for verification.
- Reduces operational costs of the facility due to the energy performance of the project. It optimized building performance via improved energy management.
- Increases the emphasis on environmentally friendly and sustainable design.
- Assists project team with potential future revisions throughout the life cycle.
  (Messner, 2011)

Code Validation
A process in which code validation software is utilized to check the model parameters against project specific codes.

Potential Value:
- Validate that building design is in compliance with specific codes.
- Code validation done early in design reduces the chance of code design errors, omissions or oversights that would be time consuming and more expensive to correct later in design or construction.
- Code validation done automatically while design progresses gives continuous feedback on code compliance.
- Reduced turnaround time for 3D BIM model review by local code officials or reduced time that needs to be spent meeting with code commissioners, visiting the site, etc. or fixing code violations during punch list or closeout phase.
- Saves time on multiple checking for code compliance and allows for a more efficient design process since mistakes cost time and money.
  (Messner, 2011)

3D Coordination
A process in which Clash Detection software is used during the coordination process to determine field conflicts by comparing 3D models of building systems. The goal of clash detection is to eliminate the major system conflicts prior to installation.

Potential Value:
- Coordinate building project through a model

- Reduce and eliminate field conflicts; which reduces RFI's significantly compared to other methods
- Visualize construction
- Increase productivity
- Reduced construction cost; potentially less cost growth (i.e. less change orders)
- Decrease construction time
- Increase productivity on site
- More accurate as built drawings
  (Messner, 2011)

3.4.3 Construct

Site Utilization Planning

A process in which BIM is used to graphically represent both permanent and temporary facilities on site during multiple phases of the construction process. It may also be linked with the construction activity schedule to convey space and sequencing requirements. Additional information incorporated into the model can include labour resources, materials with associated deliveries, and equipment location. Because the 3D model components can be directly linked to the schedule, site management functions such as visualized planning, short-term re-planning, and resource analysis can be analyzed over different spatial and temporal data.

Potential Value:

- Efficiently generate site usage layout for temporary facilities, assembly areas, and material deliveries for all phases of construction
- Quickly identify potential and critical space and time conflicts
- Accurately evaluate site layout for safety concerns
- Select a feasible construction scheme
- Effectively communicate construction sequence and layout to all interested parties
- Easily update site organization and space usage as construction progresses
- Minimize the amount of time spent performing site utilization planning
  (Messner, 2011)

Construct System Design

A process in which 3D System Design Software is used to design and analyze the construction of a complex building system (e.g. form work, glazing, tie-backs, etc.) in order to increase planning.

Potential Value:

- Increase constructability of a complex building system

- Increase construction productivity
- Increase safety awareness of a complex building system
- Decrease language barriers
  (Messner, 2011)

Digital Fabrication
A process that uses digitized information to facilitate the fabrication of construction materials or assemblies. Some uses of digital fabrication can be seen in sheet metal fabrication, structural steel fabrication, pipe cutting, prototyping for design intent reviews etc. It assists in ensuring that the downstream phase of manufacturing has minimum ambiguities and enough information to fabricate with minimal waste. An information model could also be used with suitable technologies to assemble the fabricated parts into the final assembly.

Potential Value:
- Ensuring quality of information
- Minimize tolerances through machine fabrication
- Increase fabrication productivity and safety
- Reduce lead time
- Adapt late changes in design
- Reduced dependency on 2D paper drawings
  (Messner, 2011)

3D Control Planning
A process that utilizes a model to layout facility assemblies or automate control of equipment's movement and location. The information model is used to create detailed control points aid in assembly layout. An example of this is layout of walls using a total station with points preloaded and/or using GPS coordinates to determine if proper excavation depth is reached.

Potential Value:
- Decrease layout errors by linking model with real world coordinates
- Increase efficiency and productivity by decreasing time spent surveying in the field
- Reduce rework because control points are received directly from the model
- Decrease/Eliminate language barriers
  (Messner, 2011)

Record Model
Record Modelling is the process used to illustrate an accurate representation of the physical conditions, environment, and assets of a facility. The record

model should, at a minimum, contain information relating to the main architectural, structural, and MEP elements. It is the culmination of all the BIM Modelling throughout the project to deliver a record model to the owner or facility manager. Additional information including equipment and space planning systems may be necessary if the owner intends to utilize the information in the future.

Potential Value:

- Aid in future modelling and 3D design coordination for renovation
- Improve documentation of environment for future uses, e.g., renovation or historical documentation
- Aid in the permitting process (e.g. continuous change vs. specified code.)
- Minimize facility turnover dispute (e.g. link to contract with historical data highlights expectations and comparisons drawn to final product.)
- Ability for embedding future data based upon renovation or equipment replacement
- Provide owner with accurate model of building, equipment, and spaces within a building to create possible synergies with other BIM Uses
- Minimize building turnover information and required storage space for this information
- Better accommodate owner's needs and wants to help foster a stronger relationship and promote repeat business
- Easily assess client requirement data such as room areas or environmental performance to as-designed, as-built or as-performing data.
  (Messner, 2011)

3.4.4 Operate

Maintenance Scheduling

A process in which the functionality of the building structure (walls, floors, roof, etc) and equipment serving the building (mechanical, electrical, plumbing, etc) are maintained over the operational life of a facility.

Potential Value:

- Plan maintenance activities proactively and appropriately allocate maintenance staff
- Track maintenance history
- Reduce corrective maintenance and emergency maintenance repairs
- Increase productivity of maintenance staff because the physical location of equipment/system is clearly understood
- Evaluate different maintenance approaches based on cost

- Allow facility managers to justify the need and cost of establishing a reliability centered maintenance program
  (Messner, 2011)

Building System Analysis
A process that measures how a building's performance compares to the specified design. This includes how the mechanical system operates and how much energy a building uses. Other aspects of this analysis include, but are not limited to, ventilated facade studies, lighting analysis, internal and external CFD airflow, and solar analysis.

Potential Value:
- Ensure building is operating to specified design and sustainable standards
- Identify opportunities to modify system operations to improve performance
- Create a "what if" scenario and change different materials throughout the building to show better or worse performance conditions
  (Messner, 2011)

Asset Management
A process in which an organized management system is bi-directionally linked to a record model to efficiently aid in the maintenance and operation of a facility and its assets. These assets, consisting of the physical building, systems, surrounding environment, and equipment, must be maintained, upgraded, and operated at an efficiency that will satisfy both the owner and users in the most cost effective manner.

Potential Value:
- Store operations, maintenance owner user manuals, and equipment specifications for faster access.
- Perform and analyze facility and equipment condition assessments
- Maintain up-to-date facility and equipment data including but not limited to maintenance schedules, warranties, cost data, upgrades, replacements, damages/deterioration, maintenance records, manufacturer's data, and equipment functionality
- Provide one comprehensive source for tracking the use, performance, and maintenance of a building's assets for the owner, maintenance team, and financial department
- Produce accurate quantity takeoffs of current company assets which aids in financial reporting, bidding, and estimating the future cost implications of upgrades or replacements of a particular asset.

- Allow for future updates of record model to show current building asset information after upgrades, replacements, or maintenance by tracking changes and importing new information into model.
- Aid financial department in efficiently analyzing different types of assets through an increased level of visualization
- Increase the opportunity for measurement and verification of systems during building occupation
- Automatically generate scheduled work orders for maintenance staff. (Messner, 2011)

Space Management/ Tracking
A process in which BIM is utilized to effectively distribute, manage and track appropriate spaces and related resources within a facility. A facility building information model allows the facility management team to analyze the existing use of the space and effectively apply transition-planning management towards any applicable changes.

Potential Value:
- More easily identify and allocate space for appropriate building use
- Increase the efficiency of transition planning and management
- Proficiently track the use of current space and resources
- Assist in planning future space needs for the facility (Messner, 2011)

Disaster Planning
A process in which emergency responders would have access to critical building information in the form of a model and information system. The BIM would provide critical building information to the responders that would improve the efficiency of the response and minimize the safety risks. The dynamic building information would be provided by a building automation system (BAS), while the static building information, such as floor plans and equipment schematics, would reside in a BIM model. The BIM coupled with the BAS would be able to clearly display where the emergency was located within the building, possible routes to the area, and any other harmful locations within the building.

Potential Value:
- Provide police, fire, public safety officials, and first responders access to critical building information in real-time
- Improve the effectiveness of emergency response
- Minimize risks to responders (Messner, 2011)

3.5 IFC

The Industry Foundation Classes (IFC) data model is a neutral and open specification that is not controlled by a single software developer or software company. It is an object oriented file format with a model, today developed and maintained by buildingSMART to facilitate interoperability in the building industry, and is a commonly used format for BIM. An object oriented file format is a computer file format used for the storage of object code and related data. The IFC model specification is open and available. IFC is aiming to be a global standard for BIM data exchange.

An example of how to use the IFC format is when an architect develops a virtual building model in Revit. He or she then has to send it to the interior team who use ArchiCAD. It also gets forward to the engineers who use Tekla. This creates problems to get the different format files to collaborate. The idea with the IFC standard file type is to solve this problem (buildingSMART, 2012) though there are some problems with today's format.

4 Construction Project Management

The purpose of this chapter is to introduce the reader to the Project management in large and complex construction projects. What processes that is included and how it is viewed in this bachelor thesis.

4.1 Project Management

4.1.1 A Construction project

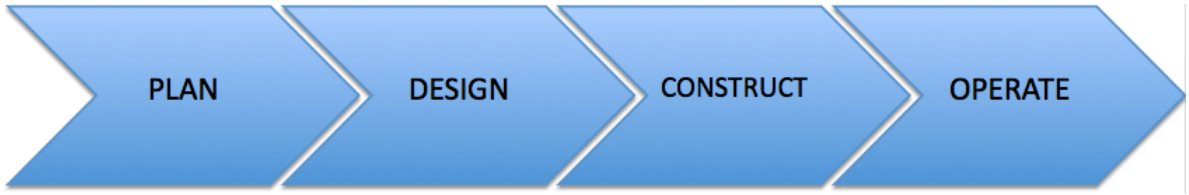

Image 8. The different phases in a construction project, http://www.bim.psu.edu

The definition of a project is a temporary undertaking to create a unique product, service or result. Temporary does not necessarily mean a short timeframe especially not in the construction industry where it often extends over years, though a project has a definite beginning and end. Some repetition does not change the fundamental uniqueness of a project, even if the structure of buildings often has a lot in common they all are constructed under different circumstances and are therefore unique (PMI, 2008. pg 5).

4.1.2 Project management

The definition of project management is the application of relevant knowledge, skills, tools, and techniques to a project to meet its requirements. The projects five processes are:

- Initiating
- Planning
- Executing
- Monitoring and controlling
- Closing

A project has different phases, processes that need to be handled with care. Therefore these processes are important to manage right:

- Identifying requirements
- Addressing the stakeholders needs, concerns and expectations throughout the whole project process
- Balancing the project factors - Scope, Quality, Schedule, Budget, Resources and Risks.

The relationship between the project factors, mentioned last, is so that if one changes most likely at least one other change. For example, if a stakeholder wants to lower the projects budget that will affect all of the other factors, the quality, scope, budget and risks. One also has to take in consideration that different stakeholders might think that different factors are more important. Therefore the project management plan set in the beginning of the project has to constantly evolve throughout the projects life cycle and the changes needs to get managed right (PMI, 2008, pg.6).

The goal with the project management is to achieve client satisfaction through the execution of projects. And to do this in agreement with contractual obligations from award through to final completion by meeting all time, cost, quality, safety and environmental objectives. This while returning an acceptable profit level for the company ensures that company policies, procedures and systems are followed and complied with (HYLC, 2013).

4.1.3 The Project Manager

The project manager is a stakeholder in the project, the person assigned by the performing organization to achieve the project objectives. Every unique project and its different organizational structure will have to set the constraints on which the project manager needs to focus.

Many of the tools and techniques for managing projects are specific to project management. However effective project management requires that the project manager possess knowledge about project management, shows good performance while applying that knowledge and personal behaviour when performing the project (PMI, 2008, pg.13)

5 Results from interviews

In this chapter the results of the interviews are presented. The chapter is structured with subheadings that reflect the topics that were discussed during the interviews. The statements consist of summarizations of the interviewees' answers. In total 7 interviews were conducted with BIM- managers, Design Managers and BIM specialists.

5.1 The interviewees definition of BIM

"BIM is a process information during an assets life cycle." *Chris Penn (CP)*

"For me Building Information Modelling is basically representing all the components in the building in a 3 dimensional way. With all the key attributes to those components identified to. Which then is able to be updated to leave a legacy throughout the life of the building." *Andrew Hallworth (AH)*

"Building Information Modelling kind of explains itself. In a construction project you create digital 3D models and dress the objects in the model with information. This is both to coordinate physically and to communicate within the project between the different disciplines. This is a process throughout the buildings lifetime, from when it is initiated throughout the construction phase, the management of the facility till the day that it gets demolished." *Mikael Kastell (MK)*

"BIM is when one establishes 3D geometries in design software, then lift over information on quantities, sizes and numbers and so on to other databases where one adds the tech-information. Then it is possible to share the information, it becomes available in a different form, and then these objects only exist in the model as case holders and nothing else. This is when I think you have started using BIM." *Gunilla Qvarnström (GQ)*

"BIM is both a verb and a noun, at least as it is used today. It is a building information model as a noun, where you have a 3D model of what should be built and where the information is linked to the objects in one way or another. The information can be linked directly or indirectly, direct in the software or indirect via a link to a database. The verb, and I do not totally agree with this, is that something is BIMed as a process. I'm not so impressed with the process they call concurrent engineering. I do not totally agree, I would like to see a more distinct description. The risk is there unfortunately rather the opposite, the lack of a process." *Peter Sundström (PS)*

“The first step is to do 3D modelling, and make clash controls. This is because one cannot build a roof if there is not a foundation to build on. Then you can make infinite number of things with this, we for example use the BIM to simulate a lot of things.“ *Ulf Persson (UP)*

5.2 BIM in the Project

5.2.1 Application and demands

5.2.1.1 NKS

5.2.1.1.1 Uniqueness

Investment in BIM

There is a great investment in BIM. When the country council traded up the project it was already stated in the contract as a BIM project (GQ). It is the first project Ulf has been involved with where all the disciplines draw in 3D (UP).

Ambition to use the digital material in FM

It is the first project for both Ulf and Peter where they are planning to implement BIM in the FM in an extensive way (UP)(PS).

It was agreed early in the planning of the project that they were going to hand over the BIM-model with the documentation of facility operation and management connected to the objects in the model. Peter expresses a deep admiration by them who was enough foresighted and managed to put the BIM bar so high in this project. Since the rotation period is so long in a project in this scale, it takes around 10 years from the demands are set to the stage where it is realized. In the BIM-world there is a lot happening during 10 years. Peter believes that the integration of BIM level is so high that the building when finished 2017 still will be at the front line in the industry. It is one thing experimenting and pushing the boundaries of what is technically possible in a small project. When doing it in such a large scale as in NKS one also demand a lot on within what processes ones use the technique (PS).

Environmental profile

There is a great investment on the environment profile on this project. One has chosen to integrate BIM in the environmental requirements by linking the material lists to the BIM-model. Thanks to this you can highlight an object in the BIM-model and get the information about the materials in it. You can also highlight a specific material in material lists and find where these are situated in the BIM-model (PS).

Collaboration over borders
The wide international collaboration between Sweden and the United Kingdom is something that makes this project unique. The NKS has also received help by Skanska in the U.S. when providing an efficient platform for BIM in the Facility Management (PS).

5.2.1.1.2 Driving BIM
Peter overtook the role as a BIM manager a bit into the project. He believes that people already in the research phase realised the possibilities with BIM. There was a drive to run this as a BIM-project from both Skanska Healthcare, the County Council and from the Consultants. They saw the possibility of this becoming a flagship in the industry for everyone involved.

Who is actively running BIM is different in various stages. Skanska Healthcare and the County Council formed the requirements and demands for what was going to be achieved. Then Skanska Healthcare together with the Consultants developed the systems and the BIM- models in the design phase to realize those requirements. When Coor, the Facility Manager for NKS, will operate the building they will manage the BIM-model the same way as they manage the building. Although Skanska as an owner and client has the overall responsibility to ensure that the demands are achieved, driving BIM is a bit like a relay (PS).

5.2.1.1.3 The demands
The exact definition of what is to be handed over is not specified in the contract or in the agreement (GQ,PS). It is very generally written, this is to be a BIM-project and Skanska Healthcare is to deliver a BIM-model with documentation regarding facility operation and management. The BIM-model should still be relevant when Skanska hand over the project to the Country Council after 30 years of operating the building. Peter, Gunilla and Ulf believe that the people who planned the project had a vision of what the effects of using BIM would be, for example more efficient document management etc. What they did not knew in detail what they wanted with BIM nor what the technology was capable of; this would explain the lack of detailed described demands regarding BIM.

Since the contract was composed in 2009 there has happened a lot in the BIM world. Something that was considered world-class back then is looked at as pretty standard nowadays. The demands move up as the technology becomes available. Peter explains that it is important not to loose the focus in this, BIM should not be a goal itself, the goal should be to create overall value in the project (PS).

5.2.1.1.4 Software

In NKS they work with a broad variety of software. The architects and some constructors are working in Revit. All the engineers are working in Tekla. Some constructors works in AutoCAD 3D and MEP are working in MagiCAD, a version of AutoCAD. The final BIM-model will be handed over in a version of Navis Works where all the separate disciplines models become one model (PS).

The major part of the technology they implement in this project did not exist by the time the contract was put together but today it does. Thought they do apply it in a much greater scale than has been done before (PS).

In NKS they are using a project portal for publishing legal documents, 2D paper drawing, digitally as PDFs and together with the BIM-models. Out on the site there are some Ipads situated which enables an easy access to the portal (PS).

5.2.1.2 NRAH

5.2.1.2.1 Uniqueness

Investment in BIM

There is a great investment in BIM in this project. Andrew believes that because of this reason there are many people following this projects outcome. There have been some previous large hospital projects done in Australia though some have been made only with 2D drafting; others have used 3D but not BIM. This one is the one that has gone the extra mile (AH).

Ambition to use the digital material in FM

There is an ambition to use the BIM-model for more than just designing the building. The aim is to create a legacy. Primarily the model will be used in terms of defects and repairs. It will enable a record and to easy send the defects to the trade contractors and get it fixed quicker. Another aim is to hand over something useful to the FM. They could if using the model, easy find the key attributes of a particular component in the BIM-model. Say that the FM start getting issues with a certain type of light fitting on a regular bases, then they can do a search in the model that will show all those light fittings, what they had to replace and when in the project. This is how BIM should be used (AH).

Earthquake resistant

This is the first hospital built in Australia that has to stand in a 1 in 500 years earthquake. This creates some technical challenges. In the due of the design

phase the consultants used the data in BIM to analyse the seismic activities, the wind loads, solar effect and the carbon emissions (CP).

5.2.1.2.2 Driving BIM

The South Australia Health Partnership (SAHP) was aware of BIM but they did not drive it. Instead it came from the contractor side, where the development director from the Hansen Yuncken saw the benefits and said that this had to be done to help change the industry (CP).

5.2.1.2.3 The demands

One clear demand is to promote construction perspective, which enables them to get quantities out from the model very quickly. All the intelligent information therefore has to get added to the FFE.

Even if it is not a demand, there is an aim to create a legacy. To not only use the BIM-model for the design, construct and build but that they will hand over it to the FM as an add note. The aim is that the FM contractors will update and log the changes they do against the model. Regardless if it is a small change like a light switch or a big renovation. The BIM-model should be kept as built and as up to date as possible to record what has happened throughout the life of the building (AH).

5.2.1.2.4 Software

In NRAH they are using different software to suit different purposes. Revit has been used as the main design and construction detailing program. Right from the start this was going to be a challenge due to the limited local availability of required resources. Naviswork was also used to compliment Revit as the “virtual communications” tool. Vico was used as the 4D and 5D tool due to its interoperability with the Revit data and skills locally. HYLC have also used Timeliner and evaluated Synchro on the project (CP).

The platform the design team is signed up to is named Aconex. The extranet platform was used to help manage the collaboration of the Revit models and the large amount of drawing data (CP). So Aconex is NRAH’s default and data management system. In Aconex they can do private correspondence, general correspondence, generate reports in terms of what RFI’s have been observed, what things you have got to action etc. It also archives the record of what happens throughout the project and why decisions are made, it is like an audit trail what you end up with. On the platform the models also gets reviewed by Aconex (AH).

5.2.2 Compromises &Challenges

5.2.2.1 NKS

5.2.2.1.1 The Facility Management

Because the definition is not clear

The definition in the projects agreement is not clear about what it means to use the model in an operational and maintenance perspective (UP). Because of this there has been a constant discussion where people are trying to interpret these definitions the best they can (GQ). This has led to challenges and confusion throughout the project from the commissioner of the construction project, Swedish Hospital partners to the hired builder Skanska Healthcare down to Coor Service Management for the FM of the building (UP).

To give an example, in the agreement it is not described in detail how the information is to be linked to the model. Neither less a list of demands of what level of detail that is to be delivered in the model; therefore this is something very dynamic. All the disciplines have to find the right level of their information together with the FM (PS).

The FM is not used to setting demands

The FM, in NKS's case Coor, is today not used to setting the demands of the specification that enables them to use the 3D model in an efficient way. This has created a lot of discussions about what different words in the contract means. One example is the word "digital content/material" that can mean many things. It can be interpreted as a scanned handwritten note or as a very intelligent 3D model. Ulf believes that the FM needs some more time to mature in setting these demands (UP).

Discipline keeping the model updated

Before Skanska hand over the building to the Country council changes and rebuilds will most likely have occurred. To keep the models possible tremendous value, the model has to be central in the administration as something they have to maintain and keep updated (PS).

5.2.2.1.2 People

Experience

People in this project have different experiences with technology and with BIM. There is always a threshold when introducing new tools or methods since they require extra energy. Ulf describes with a curve, if the energy level is horizontally at 60 when working the traditional way, when introducing a new tool the energy level rises to 80 for a short period to then drop down to 50, still doing the same thing. This hump occurs with all news no matter how amazing they are. Also depending on how much pressure is on the person

receiving the new technology, he or she is also different receptive to news (UP).

Matured
Peter thinks that everyone working in this project would agree that they have gain a lot of experience today compared to when they started. If they look back at the compromises that were made they would have done some things differently (PS). Mainly it has to do with where BIM has matured, which can even be an individual level. BIM in design for example was well established already when the project started. BIM in production on the other hand, that is an example of where it has been visible to see new opportunities rising during the time of this project. This is because the technique and the handover support to the production have evolved as well as the acceptance of those who work in the production has increased. It creates completely different possibilities today to actually push the BIM-development in the production stage (PS).

A bit in to the project there are some changes that can be made and some that cannot when new opportunities arise. Early in the project both the CAD-manual and the software get adjusted to meet the requirements in the contract. After this it is more difficult to make changes, one becomes more restricted. New opportunities can sometimes require too much clean up work to review and amend (PS).

A practical example of something that could have been done differently was the design of the staking support in the production stage. When one installs a wall it is not necessarily the centre of the wall that is interesting. Because the different use of the rooms makes the wall-structures different. So what is really useful is the line that marks the ”head track”, the rail that is installed in the ceiling and floor prior the wall and is where the studs are put in. To have the information in the model of exactly where the rail centre point was, would have been important if they were to use automated staking with laser indexing. If this would have been known in an earlier stage and they would have decided to use laser indexing, then it would have been an easy demand on the consultants. Then the architects, in this case would have included that information in the models. To add these demands as late as when they realised this possibility in NKS, would have been almost is impossible. This is now something that must be taken it as an experience to the next project (PS).

5.2.2.1.3 Software
Contents
Most suppliers do not offer digital contents of their products and the ones that does unfortunately often do not fit the right template, either because of it being

too large or detailed. In the NKS the architects, White Tengbom team, have a group that works specifically with creating contents. MEP also has to create a lot of their content themselves (PS).

5.2.2.1.4 Communication

A constant discussion is regarding the discipline, how often should the model on the server get updated and when should the project planner start using the new updated model. Ulf believes that this might have been an easier discussion before working digitally, then it was simply the next time you received the new round of drawings. Now a new routine has to get introduced where the models gets updated and then officially published at a certain time with the changes marked in a certain way. This because one cannot pick up a new model every half a day, not even every day and barely every week. There must be discipline to know what one is working with (UP).

5.2.2.1.5 Measure the effects

It is difficult to get a clear view of the effects of BIM in this project. Peter does not believe that it in the NKS project will be possible to produce a return of investment on BIM.

It is very difficult to draw a line where design ends and BIM begins, what are BIM-related costs and what are just traditional planning costs? Because of this it is difficult to find out an exact amount on how much money has been invested in BIM. Only qualitative estimates can be provided, though it is still difficult to define. In procurement for example a person could get an estimate from the model in one hour instead of in one day thanks to the use of BIM. This shows a very positive picture on a local level though it is important to weigh these benefits to the money that have been invested in the design phase to enable BIM. So because it is impossible to show exact numbers on how much is invested to enable BIM it is therefore not possible to weigh these amounts against each other. After all, Peter is confident that they have got value for the money invested in BIM (PS).

5.2.2.2 NRAH

5.2.2.2.1 The Facility Management

Most current systems that the FM providers are using are not really BIM-enabled at the moment. Because the NRAH project is a PPP a part of the project team is a company called Spotless who are the FM providers for the hospital. Spotless had already chosen QFM as their preferred FM System, which in itself will present challenges as it comes from a traditional FM background (CP).

Chris explains that the FM market is driven by what is going on in the design industry. At the moment Revit is very common in the design industry but the market has not really had enough reliable data yet for the FM system to occur and get better value and more benefits out of Revit and the data that Revit is producing. So now most of the FM system providers are developing their systems. This is like any other industry, the market does not develop anything if there is no one calling for it. Because of this there has been a focus from Chris and his team to push Spotless to get the FM and QFM developed (CP).

There is another gap between the FM systems and the Building Management System (BMS) who duplicate the same information. It is the integration of the BMS into the FM, which will use the BIM-data and that is also another big challenge (CP).

5.2.2.2.2 People

Experience

Chris says that it is too early to say if the general participant of the project sees the benefits of BIM (CP). Like with anything new it lies in the human nature to be resistant and to not quite see the benefits at first, no one likes being a Guinea pig. But after the first involvement with BIM, people can start seeing the benefits (AH).

In the NRAH project only very few had previous experience with BIM. Many had experience of 3D modelling but BIM requires more. The health planners were probably the most experienced group, used to ca 30-40 % in terms of what was required with BIM. They had previously used planning software with codes and extracting these codes, which is a bit like a data access management system. They had to be very careful with where they but the weight of the healthcare machine in the room, then the data just get extracted in order to produce space data sheets. This meant that health planners had some knowledge in terms of the processes that has to be followed when working with BIM. Architects on the other hand had in general not much experience with BIM. Because of the mix of nationalities from all over the world in this project there were people that were comfortable using BIM (AH).

In NRAH there is a huge need for education. At the moment there are 18 contractors that are trained on weekly bases but there is going to be about 100 shortly. But not everyone gets trained in BIM. The worker pouring the concrete on site probably does not have to learn about BIM yet, it is a step-by-step process. And people do not always adapt to the new technique as expected. Some of the contractors that the project team thought would naturally adopt to BIM because of their previous technology experience have

actually been the more resistant. They have laid their focus on finding reasons why they should not be working with BIM instead of just integrating it. As well as the opposite, people who they thought were never going to use BIM have picked it up very well. It is of course important to remember that this is one of the first big projects in the state that is implementing BIM and that it took 4 years for the project to get to financial close. One way that Chris uses to show people the benefits earlier is showing previous successful projects and that people have been working with BIM for 20 years. When something is new it is easy to think that it is not going to work. Another thing is that unfortunately most of the people get together on one project, they start understanding what this BIM is about, and then the same people do not work on the next project together. A person really needs the second project to actually see the benefits (CP).

Mature
There are a lot of lessons learned in this project. Not everything was right in the contracts. Chris explains that this follows the same line as lots of major project around Australia. The industry needs to work more together. Until there is a consistent set of documents that the industry for these types of construction projects there will be this problem. Chris is now, long after the contracts were signed, doing what he can to plug the holes and to put them right after the event. This is a constant uphill battle trying to make contractors do something after they signed up (CP).

5.2.2.2.3 Software

BIM-levels & Analyses
Chris explains that 5D design really is a business process and relies on a company to sort out their whole business workflow process. In the NRAH they are now doing 5D design but via with their own database, linking costs together without necessarily relying on any intelligence from the models. They are then adding it to the data and using the outputs in a schedule, adding the costs into a schedule later. From an estimating perspective it would not have been possible to use any content to produce structured output early on in the project, as they have been creating from day one all the health equipment and all the medical equipment etc (CP).

Contents
Unfortunately there is not a lot of international communication between suppliers in Australia and anywhere else in the world. Before the project team asked suppliers to contact their counter parts in America, the UK and Europe some of them had never heard of BIM or the different software. Half a year after Chris raised the question some suppliers had found libraries from other countries. By that time the architects had already gone away and created a lot

of the contents. In this project they are trying really hard to promote the BIM methods, libraries and the national object libraries but everyone is still doing their own thing. There is a need for industry wide protocols and standards (CP).

The NRAH project has set up a shared LAN drive to enable better collaboration of the Navisworks files during clash detection. They will be using ZUUSE as their Field BIM system but have also tested BIM360 glue (CP). The size of the BIM-files has been a big issue. If additional parameters are added to the object families this increases the file size and the software works slowly. This is why the model of the building has to get split up into agreed design areas to become manageable (AH).

5.2.2.2.4 Communication & Discipline

There has been a very steep learning progress on this project. This even if the designers were used to modelling in 3D with all the software packages around it before the NRAH. When working with BIM the designers have to think a lot more upfront and from a designer perspective this result in more time consumed. When modelling the component they have to put all the components in to it, the size, the weight, the finish etc while if your just drawing in 3D you do not need to do that. What they end up producing on the other hand is something that will be of great use in the rest of the buildings life, a BIM model with all the attributes attached to it. Looking at the project, as a whole there is more time spent in the front end but you save more time in the back end (AH).

Andrew explains that unfortunately the construction industry, particularly trade contractors, is very resistant to change. Because they see that they are exposing themselves to risk that might not be able to manage. When new products come out on the market you find it very difficult to get trade contractors to adopt it unless someone like the client forces them to use it because they can see the benefits of it. It is only when you get that momentum going that you see the wide adoption (AH).

When Chris entered the project the consultants had already created the execution plan and everyone was doing their own thing. It took time to make them adept to the “we approach” as Chris describes it. The main issue always is around people because everyone is an expert and everyone wants to do something different. As a result, sometimes people spend more time on why they should not be doing something differently, instead of just complying with it. The reality with BIM is that the industry does not like and cannot manage the discipline. BIM is making the process transparent and it relies on discipline. They basically had to make the project participants address the

discipline within their own very large team, 60-70 Revit users plus team leaders. The MEP services consultants were always going to struggle so HYLC brought the MEP Contractors onboard early. Chris and his co-workers are also making the consultants deliver to a level of LOD200, which is providing a far better level of co-ordinated information than contractors have had before. The weakness is that it also highlights where the engineering content is missing (CP).

The project has had 14 months of Client User Groups to establish the initial brief, which although closed out it has involved over 450 meetings to date as the original brief was not clearly communicated to the users (CP).

Chris explains that every dollar that is spent on hardware should also be spent on training and awareness, because of the large churn of people in these large projects. There should be a disciplined introduction when you bring new people in to the project to bring them up to speed. Unfortunately because the industry is not used to discipline this is an issue that constantly has to be stride for. The data in Revit is so big that it is difficult with the right level of housekeeping. Therefore it is so important with individuals understanding and how people manage the adoption of the technology, it is a cultural thing (CP).

When designing the hospital or any complex building in BIM it is important to have an absolute agreement between the consultants in how you are going to break the building up and in terms of the model. That sounds easy but it becomes a bit of a battle since the engineers prefer to work by building movement joints. The service engineers tend to want to do it floor by floor. The architect seems to want to do it by clinical department by clinical department. That is all related to how they design. So key point nr 1 is to have this agreement when having a large building and using BIM, so that people can be working in a certain way and when putting the models together it will launch correctly. Unless you get a unlimited memory size and all the supporting for that memory size, which is not really necessary. Dividing the building has been a big issue in this project and there had to be a compromise (AH).

In NRAH there are various levels of design because, on the services for instance, the consultants take it to a level of detail in terms of coordination. And then Andrew goes to the trade contractors with what people are actually going to manufacture and install. The trade contractors take the model and the manufacturers do their shop drawings in the model. So there are different stages of levels. The models got to meet to certain status of design for it to actually be delivered to the trade contractors in this project, basically finish the services. After the rotation the model comes back with another level of status

and that is what gets built. It is called level of design model 200, 300, 400 and so everything that enters the model has a status (AH).

5.2.2.2.5 Measure the effects

Chris means that everybody is measuring the effects of BIM in this project because it is a very tight program. More to do with the design and the construction rather than with BIM, it is a PPP project for a 1,8 billion dollar hospital and a 2 year design with 3 years to build. There is some very stringent KPI's that the (results) consultants are getting monitored against. Chris tried to get some KPI's put in on early days on the BIM but it was too hard because they were all picking it up. What one can tell is that what the participants' level of understanding and what they produce is approximately ten times better then what they did when they started. Chris and the project team are trying to come up with some other metrics but this has not been successful yet (CP).

5.2.3 Effects on the Project management

5.2.3.1 NKS

5.2.3.1.1 Project Integration Management

Advantage

BIM enables people to get an earlier understanding; especially when using BIM to manage information. In this kind of complex projects there are a lot of people working in different teams with different things but inside the same room. The architect has one perspective, what is the room going to look like? The engineer has another perspective, what is the clean function of the room? Their work will affect each other's. So there is a very big win to have a central information hub, in NKS this is basically the architect's model that is connected to different databases. It becomes simpler. It is easier to do clash-controls for example since you have gathered all the information in one place (PS).

IFC

IFC is good for things like clash controls, model checks and 3D viewing (GQ).

Disadvantage

IFC

Gunilla explains that they tried to use the IFC format in NKS. Though she thinks that the IFC format is quite clumsy. She prefers a more direct solution. When they tried IFC for the energy estimation models they discovered a number of problems and difficulties. One problem was the issue of information loss, another one was when trying to export the structure models

from Tekla and import in Revit via IFC to Revit, which did not work at all. In Tekla every single screw and welding is drawn and therefore when importing them in to the Revit models every tiny detail is visible which is not good (GQ).

5.2.3.1.2 Project Time and Cost Management

Advantage

Peter is convinced that this project would have been more costly without BIM. One of the processes that benefits a lot from applying BIM is in the Design. In Design they for one get an early BIM model that they can co-view and understand (PS).

Even if the overall project manager often finds it difficult to see how BIM will benefit the project and think it is unnecessary and cost them too much, one thing that is easy for them to see the advantages with is the clash-controls. Therefore clash-controls are quite easy to implement in almost every project (GQ).

5.2.3.1.3 Project Quality Management

Advantage

Since the builder have an obligation to report where the inbuilt materials are situated they have come up with an easy access way to do that in NKS. The demand is nothing unusual, though the fact that they have linked the digital material lists to each object in the BIM-model is. The option would have been to deliver the lists in paper format, which is not very user friendly and both difficult to maintain and update. Thereby they have integrated BIM in the environmental requirements (PS).

The people involved in the project are able to do two different types of analysis thanks to the BIM-model: data set analysis such as energy, acoustics, cost estimate and personal analysis. A personal analyse is where a person can study the model and understand the building and come to quick conclusions. Personal analyses are very common in NKS even if data set analysis not so often. They do perform data set energy analysis of all the different parts of the building, while cost estimates based on the model only are performed to some degree at an individual level (PS).

Ulf believes that the installations are so complicated in today's healthcare that even the people who planned great hospitals in the 70s and can visualize drawings without 3D modelling, they would have struggled without BIM in this project. Also, nowadays the designers are not trained to have the inner 3D visualization that is projected down on 2D drawings. So to be able to perform

the installation design in this hospital, which is really the most difficult design you can do in that sector, BIM is an absolute necessary tool (UP).

5.2.3.1.4 Project Human Resource Management

Advantage

BIM is very user friendly and makes help people understand what is to be done and why (PS).

5.2.3.1.5 Project Communication and Stakeholder Management

Advantage

BIM has great opportunities when it comes to being user interface. Even though it does not create any new any information, only new possibilities when it comes to analysing but the main thing is that it organizes the information in a way so that everyone can understand it. If they would have used excel lists in NKS some people would have had trouble with understanding the different numbers and acronyms. It is easy to understand if you go into a 3D model and can see the window exactly as it looks, click on that particular window and get all the documentation about that window. Communication is important in all organisations but especially in a large complex project organisation like NKS. BIM is one of many ways to improve the communication (PS).

As a compliment to the supplied paper drawings, listings and descriptions that are included in the construction documents, there is access to the same information on a database. One do not have to go into the model to receive that information, even if it comes from a database that is aligned with synced to the model. Access to the database helps very much in quantity calculation for example (PS).

In Peters role as a planning and design manager he feel like BIM makes it is easier for him to follow up the design. He receives updates all the time and if something is not drawn in the model it is easy to find out why. It is easy to see how far the design has come and every week he can publish models and see that everything is ok. It becomes very transparent. When Peter sees the model he can make his analysis, he can see the project and get a clear picture of the building and today's design. This enables him to come to certain conclusions and ask the right questions to the consultants (PS).

Disadvantage

Because BIM makes everything transparent it might increase the expectations to some degree. If the client only gets to see 2D drawings he or she cannot see all the clashes and become blissfully unaware of these. When BIM is

implemented people expect the design to get better but what happens are that all these clashes become visible. This can creates a bad balance between the expectations and the actual result; the result is not necessarily of lower quality but if the expectations increase it might feel that way (PS).

There is a risk with the level of detailed information in the model that is accessible for everyone. When the project is of NKS's size it might not be of advantage for everyone to have access to all this information. The overall project manager for example might risk falling down in the details in areas other people are responsible for, when he should be focusing on getting the processes in the overall project to work (PS).

5.2.3.1.6 Risk Management

Advantage

BIM makes the design and engineering transparent (PS).

Disadvantage

Peter draws a parallel to when the mobile phones came. When you adapt to a new technique, you add what you currently have with what the new technology enables and take the sum. Today + New Technique = Result. This is never the reality he means; the new technology will inevitably erode some of the old techniques and knowledge. When the cell phones entered our lives we thought "this is nice, now we can call anyone whenever we want" but this also changed our way of living. To be rational, people stopped showing up on time because they can always call and say that you are late. This is one of Peters worries with BIM. That implementing this technique will erode some of the existing discipline on planning the design of a building. That we might not clarify to the same degree the restrictions the different disciplines have. That we will not keep setting that structure on how to do the design because BIM enables us to constantly work integrated and quickly manage changes. He is not saying that this has happened in NKS but raises a slight concern like with all developments (PS).

The status of the information in the model can be a challenge and risk. Design is a process, something that goes back and forth. Even when using BIM it is important to complete the different statuses correct. To name the design a program of action, system documents, construction documents, certain criteria and discipline still has to be achieved. If not, there is a risk of confusion for example, only a few weeks in to this project the BIM-model had a floor, not necessarily the right floor all though a visible floor. No one is guaranteeing anything in the design until they have delivered it with the right status. This is a risk especially in these large projects. The risk that people take non accurate

information that no one take ownership in from the model and make decisions based on that fake picture of the design (PS).

5.2.3.1.7 Project Procurement Management

Advantage

At an individual level people are working with procurement in NKS using the model to extract quantities which then feeds into the calculation. Lean procurement has been used in some of the procurement packages. Logistics analysis has been made based on the model for example when identifying roads for some big equipment etc (PS).

5.2.3.2 NRAH

5.2.3.2.1 Project Integration Management

Advantage

BIM enables the people involved in the NRAH to get an early understanding (AH).

5.2.3.2.2 Project Cost Management and Time Management

Advantage

Chris is convinced that if they had not applied BIM to the project they would have needed twice as many people. They would also have had the risk of overrun and lack of attention to coordination that would have resulted in roughly twice the length of the program (CP).

Something that will make everyone demanding BIM is if one can prove to the financial people that there is such a large amount of contingency on every project and that with the help of BIM we can decrease the contingency. For instance contractors often have had to sort all the issues too late in a project which often ends up costing more than if this issue is solved in the design phase (CP).

With BIM Andrew explains that one has to use a different method of working, one has to be more collaborative. It is in having trust in other consultants in pushing models around. The consultants have their own individual models, but then there is a coordinated model so all the consultants have to download, the federated model (AH).

5.2.3.2.3 Project Quality Management

Advantage

Chris explains that working with BIM is not just the reliability to manage risks, it is managing certainty, making everything transparent and actually

proven in quality. Even if there still are changes occurring in the model because of processes with the client. Hopefully when they start to set the building out on site digitally, the level of coordination and the accuracy will be a lot better than in a traditional project (CP).

5.2.3.2.4 Project Human Resource Management

Advantage

One positive factor of using Aconex Chris explains is that they can click on an area of the model that will call down the 2D drawings quick and easy from the platform. That enables the workers on site to get easy access to the relevant drawings. This is a part of the field BIM strategy that they developed in NRAH to take the data on to site. Another part is that the workers on site can fill out the digital forms for the QA signoffs on their mobile tablets. This enables the project team to use that data to get progress-reports and later link the progress-report to a Naviswork virtual model. Finally one can click on a column and see what information that is captured (CP).

Disadvantage

Certain of the managers can see the benefits and others certain do not interact with the model and still looking for additional drawings (CP).

There are still issues with the people who are not hands on. One of the biggest issues is that they might not have the appropriate architectural or engineering experience. Chris explains that if you look at the structure engineers they have adopted the new technology very well because they have always been drawing things that actually had to get built. They can understand the prototyping while some of the architects in this project in the beginning were afraid that BIM was going to restrict their creative skills. It did not take long until those people understood how they could link the detail in with their creativity (CP).

5.2.3.2.5 Project Communication and Stakeholder Management

Advantage

BIM is very good for clash detection, looking into 3D and being able to put the models on a screen for understanding when you have meetings. Andrew and his colleagues can not only find and see a rendered pipe visually; they can know everything about that pipe; the size, the function, the origin, anything. This makes it easy to understand what the pipe is and what that needs to be done and can be done to avoid clash detection (AH).

Working with BIM requires a completely different mindset including a very structured approach. The designers need to know what attributes need to put in. Everyone then got to stay lingered to it to make sure that all the modellers

are obeying these rules. This has a lot in common with 2D drafting. There is set layers for certain consultants to drop on to. The form of the layers and the attributes has to be very rigid and additive because if it is not, they end up with parts of the model that does not hold the required information. Alternative they end up with parts of the model where the information has been placed in the wrong way, which causes problems (AH).

Disadvantage
With the architects there can be issues since they are used to working in 3D for presentation reasons. This results in that they sometimes cut corners that do not affect the look. When working with BIM one cannot do that (AH).

5.2.3.2.6 Risk Management
Advantage
Because the NRAH is a hospital one of the biggest risks there is on this project is the FFE. Because they now got a BIM data management system, that they are managing all the Revit data through, this enables them to analyse that information. They can check each functional area against what is in the brief and also manage the items of FFE against what was in the original brief. The items that the architect has put in the model that was not in the original bid can therefore be identified and colour coded thematically in the model as red for example (CP).

5.2.3.2.7 Project Procurement Management Measure the effects
Advantage
Andrew explains that thanks to the BIM model they can get estimates very quickly; number of doors, types of doors etc. This helps procurement and cost control, particularly when one build at the same time as one are designing it (AH).

Disadvantage
It is important to remember "garbage in garbage out". If the information in the model is not put in properly there will not be any useful information coming out of it. The issue of understanding how BIM works when working with it is crucial. Everyone working with the model has to understand and adapt to it because if anyone try to cut corners BIM cannot be used correctly (AH).

5.3 Future of BIM

5.3.1 3D vs. 2D

5.3.1.1 NKS

In the future Peter think that we definitely will measure and build more extensively from the BIM-model. To enable automatic staking one have to collect necessary information from the model. How it works is that one feed a portal station with the model files that are plotted with right geographical and metric values. He believes that printing everything on paper probably will become meaningless though this development has got to take some time. There is nothing stopping this development but it has to take time because it is not enough that a handful enthusiasts in the industry runs these changes, what matters in the end it is that the builders knows what information is accurate. In NKS they publish the models with each construction status separate to make it easy for the builders (PS).

5.3.1.2 NRAH

Chris thinks that the 2D drafting always will be around for extensions and alteration works, fit out works, shop fitting etc. He is not sure but cannot see them going towards BIM. Residential house builders he also thinks will probably just use 2D. When it comes to commercial retail it really depends on the view of the company. If they can see the long-term benefits on the large shopping centres then it is possible to get a change that way (CP).

5.3.1.3 Experts

Regarding measuring from the BIM model this is something that we already do today in some projects. Sometimes the model gets delivered as information documents but in NKS for example they used the models and collected the values from them (GQ).

In NKS they did something called LOD – Level of detail. It is a scale with which parameters in the model one is responsible for. Then the one responsible can say – this and that are you allowed to use from the walls, this when you measure and that when you estimate amounts. That link and disciplined way of working and communication does already exist but Gunilla believes that it will become stronger. One must be very clear with what information in the models that is to be used; one has to list down to a parameter level, what measurements and what the objects are named. This parameter on this object, otherwise there will be mistakes. There are no shortcuts (GQ).

5.3.2 Project Management and communication

5.3.2.1 NKS

Ulf thinks that the software that the various consultant groups are using today will communicate much easier in the future. He explains that there is an enormous potential development with the different software that the architect, the structure engineer/ designer and the Mechanical and Electrical designers use. They are today working in three different types of software that is difficult to connect. Today there is a lot of time spent transferring data from these models. This is something that needs to get easier, and Ulf is convinced that it will. Even if the software suppliers are looking after themselves and their own interests Ulf believes that this in a very important factor of success; the technicalities regarding the usability and the way the different software communicate today. This is today an issue already in the start up of a project (UP).

Ulf has heard of IFC and explains that it is nothing that happens automatically. That we need a common denominator that enables us to move around the information and that interleaves the models. Some software companies have been promising to solve this issue in earlier projects, but it has not quite happened yet. Maybe because no one really knows what are the industry standards and what are required. It includes everything from FM etc. We do have a pretty mature industry in some ways with some standards like how a system document, construction document should look like. Now what we need is a similar investigation regarding how to work with the model on a daily bases (UP).

5.3.2.2 NRAH

Chris is looking forward to the day when he can set up a system that can lock the consultants in a process and also manages that process. Then they can automatically publish the consultants' models on the cloud every day or week and easy see how we are making progress. He says that we are not that far away from achieving this. The problem is that there is no system at the moment that manages Revit or the processes of the Revit database in conjunction with the subsequent drawing production process as the model is always alive. M6VO and new form are coming along which are going to be a challenge for major projects to adopt and is the next kind of external portal (CP).

Chris would like to see more intelligence built in to the Revit products so the IBIM – Intelligent BIM, can start to happen. The amount of market share they have at the moment, if they were to concentrate and bring the three products

into more alignment they were to, they could probably do it within a couple of years but they have been saying that the last couple of years so (CP).

Chris is starting to feel an increased understanding of BIM out on the construction site, the project managers can see how BIM can help them to manage their team. When he explains to clients he use the analogy that BIM is like a loyalty card that the retailers brought out 20 years ago, they wanted it out but they did not know what they were going to do with the data then. Now they know what you are going to purchase before you go and buy it. The reality of the construction industry is that they need to catch the data on behalf of its client, and then it needs to show the clients how more efficiently they can run and manage their buildings. When these clients understands the benefits of this that is when they will demand it on every project. Today Chris and the project team have a specification of what they are to hand over, but he would not say that it is making the best use out of all the data, all the information, that they are collecting yet (CP).

Andrew believes that construction companies, particularly if they are doing design and build in large complex projects, will be fools not to have BIM. Because BIM helps them in a number of ways; to keep the cost control, they can see how many things that are developed measuring of the QS thanks to the different attributed etc. They can see everything in 3D, the clashes and everything else. So the development implementing BIM in the Australian industry would have to be led by the major construction companies and then they need to drag their subcontractors (AH).

5.3.2.3 Experts

Gunilla explains that the project managers are pretty far away from BIM. They find it difficult to understand BIM. Partly because they currently have pretty primitive tools for the planning themselves and find it difficult to see how these can be linked to the BIM model for instance. The project manager is responsible for the budget and the time plan so that puts them very far away from the model. Her experience tells her that they are the last group that will really understand the benefits of BIM. They feel that implementing BIM just leads to a lot of difficult questions that they cannot answer. They become frustrated and confused. This is why there is a need for information coordinators on a project management level as a support for the project manager. They try to build a team, project manager and the IT or information coordinator. That makes it easy for the PM just to forward the questions to them and they can explain to the project manager what should be done and why the model is the base (GQ).

Gunilla believes that there in the future only will become more different software and that the applications of the programs unfortunately will become more and more complicated. This will create a need to find other ways to handle the hand over to the FM for instance. The FM will find it difficult to receive this information because of the large amount and complexity of it that they have to filter through to get what they need (GQ).

There are no limits of to what degree BIM can be implemented; the hardware and software power exists. The issue that needs to get solve is the exporting and importing between different software, the amount of data and information that needs some work. Not everyone can work in Autodesk software. Mikael has experience from different software for collaborating the models, he says that IFC works pretty bad with for example Navisworks but has not found any problems with IFC and Tekla BIM sight (MK).

IFC is the only neutral format that Mikael has been in contact with. The DWG format loses the information and NWC only works from Revit to Navisworks. Autodesk paradoxically developed IFC in the early 90ies together with some other major American players, this because they saw the need to communicate between different software (MK).

Who will drive the development of BIM? Mikael explains that everyone in the buildings lifecycle has a shared interest in implementing BIM. This unfortunately sometimes results in “shared interest - no interest”, and stakeholders what to sort out who benefits the most from it and who should therefore invest in it. In this case it is most likely the client, who does often not have the time or energy to invest in new technology that they do not understand. So someone needs to tell them about it and how they will benefit from it (MK).

It is possible that there to some degree is a taboo to mention in the initial planning of the project that implementing BIM result in a more expensive design, this to have it delivered the right way. The economical benefits from those investments in design will later show in the production phase and in the facility management. It is important to see the whole picture. Also one does not have to work 100 per cent BIM, maybe start with 70 per cent – roughly speaking that is still 70 per cent won. That can be a soft start, take the parts you understand in BIM and benefit from them and use them (MK).

Status branding design is something Mikael is working very actively with. Since design is a process that has to go back and forth it is important that the designers in a large complex project can view each other’s design along the whole process. It is easy to end up in a situation where the designers do not

want to share information because they are not finished and cannot guarantee the design quite yet; when they consider themselves finished it is too late. All the discipline benefits from seeing each other's design along the way since their work affect each other's. This is a major issue today. Status branding can solve this problem; the receiving person can understand what parts of the design that is finished and what is not yet. And the exporting person is more comfortable with sharing the information (MK).

Something else that needs to be worked on is to be able to reuse the digital material in the model. Since most buildings built today, if they are public buildings for example, will have the first rebuild within 5 years. Today we do not keep the digital content updated enough so this is not possible. Most FM providers will have to learn how to handle new software and new tools but it is awfully heavy for them to do this. Then they need people like information coordinators to forward the information demands to the consultants. And these coordinators have to invest a lot of time in this, to get them to understand how they need to do to make it right because they will do mistakes all the time (GQ).

Gunilla also think that the industry does not really learn their tools. They do not come to the understanding. In her company it is not unusual that they receive Revit models for coordination, where the different levels have been used as help lines. Five level buildings with seventy-five different levels, one real level is in the model drawn as seven, which makes the model useless. That is simple knowledge about this tool, to enable it to work all the objects needs to be linked to one level otherwise they cannot get how many walls that are needed on each level for example (GQ).

There is also lack of overview of how to work with BIM in general. Gunilla think the drawings is the main problem, many people are still left in the traditional way of working thinking that the same tasks has to get done. When now there is no need for that, one should work smarter and simpler and on a joint base. If we do not understand how the tools are supposed to work and therefore push them to do things they are not designed for, they will not work. And this is what Gunilla can see that a lot of people in the industry are doing today (GQ).

Martin points at that we can already see the roles and responsibilities slowly shifting. Players will have to define and position themselves accordingly. One main aspects of BIM is that it can help improve productivity - tasks will become faster and easier to do, meaning that more output can be achieved by the same resources. He also thinks that the role of the project coordinator is

brought more into focus on BIM projects because the optimized organization of information is the key to the investment and the project (MH).

5.3.3 FM and globalisation

5.3.3.1 NKS

Ulf would estimate that it will take approximately 10 years to develop the tools and software to enable the FM to use BIM to an extensive degree. He says that we will see a lot of development in this area in the next couple of years. Once again it does not matter if one FM Company finds the information need, there still needs to be the right tools to make it user friendly. A parallel can be drawn to when Ulf studied at university in the late eighties, they could already do 3D modelling but it was not very user friendly so only very few could do it. This has been a journey and it is not really until now in the 2000s that the industry has matured and adapted to this new technique. Therefore he believes it will take 10 years for the industry to find a suitable standard in this area (UP).

5.3.3.2 NRAH

Chris does not think that the operators in the FM are such that they really understand what the extra data that BIM brings is going to do for them yet. He knows that they in NRAH are using the system they are using in NKS, ARTRA, now called ZUUSE in Australia. Though in NRAH they are not using ZUUSE for their Facility Management system. They will use COBie2, construction operation and building exchange, to transfer business data into the FM system (CP).

The spread of BIM, Chris says, in most of these major first projects all around the world are often driven by some visionary, some person, and usually it is the contractors that will see the benefits (CP).

Andrew is not sure how far BIM will go in Australia. Since they do not tend to get that many huge projects. What they do get is a lot of is big commercial and retail projects like big shopping centres. Therefore he believes that BIM would have to get insisted by these because it would help them on the FM side. BIM would have to be sold on that bases by commercial developers because what happens is probably that the fees from the consultants would be slightly higher than without BIM, but with the benefits coming at the end. You spend a bit more on a product in the beginning and you get a lot better product at the end. That is the commercial and the private sector. Regarding Government departments, they will be asking for it a lot more on particularly their larger projects because they have a long-term interest in their buildings. They rather have their information easy accessible than in books, files and drawings so

BIM would be a definite advantage for them as well. The BIM model is also a legacy of showing what has been done to the building over its life. So if you ever have to do major redevelopments in that building, you will be sure of what is inside that ceiling, behind that wall, which tends to be the problem today (AH).

5.3.3.3 Experts

Gunilla would say that we are good at cooperating in Sweden. Swedes are good at sharing information without bringing in lawyers etc. This gives Swedes an advantage of agreeing and delivering information. She also thinks that with the coordination meetings and collision checks, Sweden is quite far ahead. As well as when it comes to handing over information via models. These are some of the great advantages of applying BIM in Swedish projects; it is not so much resistance. She also feels like we let people who are interested to run these issues. Much because of the Swedish organisation structures being flat. In general the English-speaking world it is more hierarchical. One does not make these decisions of implementing BIM as a site manager or someone else, it must be someone higher up in the organisation making it. This makes it more difficult since the managers high up often find it difficult to understand what it is about and what benefits it creates (GQ).

Martin explains that one can perhaps collect some clues of where BIM is going by looking at other sectors that have adopted similar technology and process change. The aircraft and auto industries, for example, have come comparatively much further with regards automation of process through their entire supply chain. One thing he thinks is for sure; deliverables are changing and drives changes in business models.

Another way of looking at the future Martin continues that one also can consider the Darwinian view that BIM consists of a proliferating variety of applications - which will survive, which will mutate in to something different, which applications will die, will be left to evolution of the systems and the advantages of using them (MH).

Martin does not believe that there is a maximum BIM-capacity, but as one reads about more and more success stories, certain breakthroughs are being made every day. There are a lot of variables to bring together to enable an objective assessment of when an industry or a project team will have sufficient BIM-Capability and Maturity to take full advantage of BIM systems. Maybe it will be a question of luck in bringing the right people together. He thinks that it is likely that in the future BIM will be called something else, but for now short, medium and long term goals amongst industry players, whether

converging or diverging, together with state intervention to insist on BIM will play a big role in terms of speed of adoption and maturity (MH).

6 Analysis & Discussion

In this chapter relevant discussion will be brought up and linked to the theory. The chapter is structured in the same way as the previous. The aim is to analyse the result in an as objective way as possible.

6.1 Definition of BIM

The interviewees' gives roughly the same description of BIM and as found in the literature review. They highlight the 3D model of the building containing linked information and key attributes to the components in the model. Chris gives a short clear description of BIM being " a process information during an assets life cycle". Peter on the other hand explains how people use it as both a verb and a noun, the Building Information Model but also the process called concurrent engineering.

All agree on that BIM is used throughout the buildings lifetime, as a legacy. It makes people working with the different parts in the different phases to easier communicate, coordinate and understand the building and what needs to be done.

6.2 BIM in the Projects

An overview of uses that is applied in the two case studies, NKS and NRAH, is viewed in the table below. For explanations of the different BIM uses see chapter 3.4.

Primary BIM Uses	**Secondary BIM Uses**	**NKS**	**NRAH**
Existing Conditions Modelling		x	x
Cost Estimation		x	x
Phase Planning		x	x
Programming		x	x
Site Analysis		x	x
	Design Reviews	x	x
Design Authoring		x	x
Structural Analysis		x	x
Lighting Analysis		x	x
Energy Analysis		x	x
	Mechanical Analysis	x	x
	Other Eng. Analysis	x	x
	Sustainable Analysis	x	x
	Code Validation	-	-
3D Coordination		x	x
Site Utilization Planning		-	-
	Construction System Design	x	x
	Digital Fabrication	x	x

3D Control and Planning		-	x
Record Model		x	-
Maintenance Scheduling		x	-
Building System Analysis		x	x
	Asset Management	-	x
	Space Mgmt/Tracking	-	-
	Disaster Planning	-	-

6.2.1 Application and demands

In both NKS and NRAH there is a great investment and focus on BIM. Both the projects have really gone the extra mile in how they are applying BIM, this because of the large size and great complexity of the projects combined with the high standards on modern hospitals.

At NKS they are planning to implement BIM in the FM in a more extensive way than on the NRAH. A demand was agreed early in the planning of NKS, Skanska Healthcare will in the end of the project hand over a BIM-model with all the documentation of facility operation and management connected to the model. At the NRAH there is an aim to create a legacy with the model and to hand over something useful to the FM, even if there is no written requirements to the same extent regarding this.

In Stockholm, Skanska, the Country Council and the consultants all agreed early in the research phase to run NKS as a BIM-project because of the great possibilities. In Adelaide the SAHP was aware of BIM but it was the development director from Hansen Yuncken that saw its possibilities. After the decision is taken, running BIM is a relay, one stakeholder set the requirements, another one realizes them and later the FM takes over during the rest of the buildings lifetime. Everyone has a great responsibility to contribute with their part and keep the information and model accurate to make the process work.

In NKS the exact definition of what is to be handed over regarding BIM is very generally written in the contract and agreement. This is to be a BIM-project and BIM-model with linked documentation regarding facility operation and management will be delivered in the end. The BIM-model should still be relevant when Skanska hands the project over to the Country Council. In the NRAH there is no clear demand regarding BIM either though there is an aim to create a legacy, to use the BIM-model for more than the design, that the FM will use it as an add note. One demand is to promote construction perspective; this enables them to get quantities out from the model very quickly. All the intelligent information therefore gets added to the FFE.

None of the interviewees from the NKS or the NRAH believes that the people who formulated the demands regarding BIM knew neither its possibilities nor what benefits they wanted out of the technology. This resulted in that not all the right useful demands got right in the contracts with the contractors and subcontractors in these projects. There is a need for a consistent set of documents for these projects in the industry to avoid these mistakes. Unclear demands also leave a lot of responsibility on each discipline to realise the definitions in a suitable way for them. It creates confusion and extra work that could have been avoided if the contracts were more exact. This is however quite difficult to avoid when implementing new technologies and is something the industry will get more experienced with it.

The two case study projects both have a very high environmental standard to live up to, the NKS with ISA 14001, LEED Gold certificate and Miljöbyggnad and the NRAH with 4 Green stars. The NRAH also has to be earthquake resistant something that not is relevant for a buildings in Sweden.

Regarding the BIM software both the NKS and the NRAH mainly use Revit for design and Navisworks for collaboration of the models, because of its compatibility with Revit. In NKS the different disciplines work in Tekla, AutoCAD and MagiCAD. In NRAH they are using Vico and Timeline for the 4D design and Vico for 5D design. The two projects have in common that they both apply all the software in much greater scale than has been done before. BIM-files often become too large and too slow, therefore the buildings had to be divided up in phases to become manageable. Since all the disciplines prefer to design a project like this in a certain order, different to each other's, this is something that is important to agree on early so that the models can be synced correctly.

The NKS and the NRAH both have to work on Data management platforms because of the complexity and size of the projects and its data. NKS uses Skanskas' project portal and NRAH uses Aconexs'. These platforms enable easy access for all the projects stakeholders to the BIM-models, its information and to the published drawings.

6.2.2 Compromises & Challenges

Since the FM providers are not used to using BIM in their work yet there is a bit of confusion of what information is useful for them to have in the model, from an operational and maintenance perspective. It does not help that there is no exact demands in the contract of what is to be delivered to the FM provider, neither in the NKS nor in the NRAH. This creates challenges and confusion throughout the projects. Once the FM knows what they need they also need time to gain experience of working BIM-based and to develop new

tools for working more efficiently. First then, the model will hold its tremendous value for the client and the FM. Until the FM reaches this point Chris at the NRAH believe that they should capture as much data as possible in the model to later decide what to leave and what to deliver.

Not everyone had experience of BIM before joining the two projects, even if they did it was not to this level. This results in a gain of experience in BIM every day. The more experience a person gets the more positive and less resistant he or she is to using BIM and with this, new possibilities arises. Not everyone in the project need to learn BIM, even if it helps if everyone have some understanding of it. In NKS both the technique and the handover support to the production have evolved and the acceptance of those who work in the production has increased a lot since the start of the project. Most likely this will lead to more possibilities regarding BIM in production on the next project these people work in.

The suppliers of materials and products need to develop and offer digital content to a more extensive degree, in both NKS and NRAH almost all contents has been developed by their own designers which is very time and money consuming. The content has to be flexible to fit each projects template to be used in the BIM-models. This would make it possible to from an estimating perspective do cost analyses at an early stage in the project. There is a need for industry wide protocols and standards.

A reality with BIM is that it requires discipline and it is making processes transparent. The industry needs to become better at managing discipline.

Both studied projects works with status labelling of everything in the model. This is an important step in the communication of information and design that everything that enters the models has a status, to avoid mistakes and misunderstandings. It is important to have some form of checklist and criteria's that the design has to fill to reach a certain status of design.

A way to measure the impact of BIM needs to be developed. In NKS and NRAH it is difficult to measure the exact impact of BIM. The first issue is that it is difficult to tell what BIM has cost the projects, compared to if they were to use traditional design methods. This could be because of the industries difficulty with discipline. Since no exact amounts can be provided, a return of investment cannot be calculated. Meanwhile one has to go on qualitative estimates, what can be observed is that the productivity increases. The interviewees from NKS and NRAH are confident about the great value the project get for the money invested in BIM. Looking at the projects as whole

there is more time and money spent in the front end, design and planning, that results in saved time and money in the back end, construction and FM.

6.2.3 Effects on the Project management

The greater effects in the project management from implementing BIM in these projects lies in the;

- Project Integration Management
- Project Time and Cost Management
- Project Quality Management
- Project Human Resource Management
- Project Communication and Stakeholder Management
- Project Risk Management
- Project Procurement Management

6.2.3.1 Project Integration Management

BIM enables all the stakeholders to get an earlier understanding about the hospital. In this kind of complex projects it is a good thing when the processes becomes more transparent so everyone can get an overview of the projects progress and understand and review the design. The negative effect of this can be that those who should look after the overall project falls down in a detailed perspective. Another issue could be that someone without knowledge of the models status levels can make decisions based on unfinished design.

6.2.3.2 Project Time and Cost Management

A construction project as large and complex as the NKS and the NRAH would have required a lot of more time and money if BIM not had been applied. When planning the hospitals the disciplines can solve problems that would have had to be solved on site, clashes in FFE for example, because they can work more integrated thanks to BIM. Also, if they had not used BIM there would have been a need of more people and a greater risk of overrun and lack of attention. Unfortunately there is not yet a possibility to put numbers on these savings concerning time and cost.

6.2.3.3 Project Quality Management

Working with BIM increases the possibility to manage risks, it is making everything transparent and actually proven in quality. The level of coordination and the accuracy will be a lot better thanks to BIM.

It is possible to do different types of analysis thanks to the BIM-model, data set analysis and personal analysis. This is useful to ensure the environment

standards. The installations are so complicated in today's healthcare that it would have been almost impossible to build these without 3D modelling.

In NKS they will, thanks to BIM, be able to deliver easy access material lists linked to the model through barcodes on all the material. This will also allow easy maintaining and updating. BIM is thereby included in the environmental requirements.

6.2.3.4 Project Human Resource Management

BIM is very user friendly and helps people understand the building and understanding other disciplines restrictions and goal.

At NRAH one positive factor of using Aconex is that workers on site can fill out the digital forms for the quality assessment signoffs on their mobile tablets. This enables the project team to use that data for progress-reports that facilitates appropriate human resource planning.

6.2.3.5 Project Communication and Stakeholder Management

Communication is important in all organisations but especially in large complex projects like the NKS and the NRAH. BIM is one of many ways to improve the communication. BIM has great benefits when it comes to user interface, it creates new possibilities to analysing but the main thing is that it organizes the information in a way so that everyone can understand it. Working on a platform base with BIM provides an easier access to information for all stakeholders.

As a design manager it is easy to follow up the design when working in a BIM-project. The manager can understands where the design is and he or she can analyse and come to conclusions and proceed to the next step or solve issues.

BIM requires a very structured approach that needs to be followed by all the designers. If not, parts of the model will be useless. This might require set work processes.

BIM is very good for clash detection, looking into 3D and being able to put the models on a screen e.g. during meetings. In NKS they tried to implement the IFC format when coordinating all the models in to one. They discovered a number of problems and difficulties like the issue of information loss and different level of visible details.

Since all these clashes in the design gets visible it may appear for some stakeholders that the design holds lower quality than if the stakeholders only saw 2D drawings, blissfully unaware of these clashes. If they get informed about that this is how the issues gets solved earlier, and that it is a benefit of BIM there should not be any misunderstandings.

6.2.3.6 Risk management

Because the NKS and the NRAH are modern hospitals one of the biggest risks lies in the FFE. Thanks to the BIM data management system they can analyse, do clash controls, compare items in the model to what was in the original brief and more.

Something that could become a risk on the other hand is if the new technology erodes some of the existing discipline when planning the design of a building. BIM does not solve everything, there still needs to be a locked in structure on how to do the design. BIM enables us to constantly work integrated and quickly manage changes so people might get a bit lazy with deadlines and good quality design.

6.2.3.7 Project Procurement Management

In both NKS and NRAH people are working with procurement based on the BIM-model. They can use the model to extract quantities very quickly, which saves a lot of time compared to traditional estimates. Lean procurement has also been used in some of the procurement packages. This helps procurement particularly when building at the same time as one is designing it. It is important to remember here that if the information in the model is not put in properly, one cannot get any useful information out of it.

6.3 Future of BIM

6.3.1 3D vs. 2D

Constructing from the 3D BIM-model without the use of 2D drawings will most likely happen in the future even if 2D drawings might be around for alteration works and residential builders.

In the NRAH and the NKS they are using the model more and more in production, to a higher extent in NRAH than in NKS even if they both are collecting measurements from the model. All that matters in the end it is that the builders know what information is accurate in the model or on the drawings.

6.3.2 Project Management and communication

The different software the disciplines use will have to communicate much easier in the future. There will most likely come more software and therefore a greater need to export and import between the different environments. IFC could be a solution, though it has some problematic issues that need to be eliminated. There is a huge need for an independent format that enables us to move around the information between different software easy.

Industry standards need to be developed concerning BIM, for example standards for the FM and other disciplines. With new complicated software creates a need to find new better ways to hand over to the FM. The FM will find it difficult to receive this information because of the large amount and complexity of it so that they have to filter to get what they need.

There will probably come processes that automatically manage the processes in design for example. Then the consultants' models would get published automatically on the platform every day or week and it would be even easier to see the actual progress.

More and more intelligence will be built in to BIM so that IBIM happens in a greater scale. BIM will also be used more advanced on site in the production of the building.

The industry will develop a greater innovation for new tools and techniques and discipline to learn and understand how these are to be used.

6.3.3 FM and globalisation

It will take some time for the FM to develop the tools and software to enable the FM to use BIM to an extensive degree and find suitable standards.

The spread of BIM in most of these major first projects all around the world are often driven by some visionary, some person, and usually it is the contractors that will see the benefits. The client is the one who benefit the most from BIM because of their long-term interest in the building and should therefore initiate BIM in their projects. Large construction companies as well, particularly if they are doing design and build in large complex projects will realise the benefits with BIM. The BIM development has to start from the top with the big construction companies to then eventually spread down in smaller companies and projects.

It will be interesting to see how far BIM will go in Sweden and Australia. Australia gets a lot of big commercial and retail projects like big shopping centres that would benefit on the FM side in BIM. Government departments

will be requiring it a lot more on particularly their larger projects because they have a long-term interest in their buildings. In Sweden it is easy for people interested to run BIM in project since the organisation structure is quite flat. In Sweden BIM will also be required in the bigger construction projects.

Looking at other sectors that have adopted similar technology and process change the aircraft and auto industries, for example, have come comparatively much further with regards automation of process through their entire supply chain so this is likely future with BIM.

BIM might also mutate in to something different to be of greater use for the construction industry. Breakthroughs are being made every day.

7 Conclusion

The purpose with this chapter is to present the key conclusions of this study. The conclusion will be answering to the aim and purpose of this bachelor thesis. There will also be outlined a number of proposals for further research.

7.1 Key conclusion

7.1.1 BIM in these projects

In the NKS there is a requirement to deliver a BIM model with the information and attributed linked to the content in the model. The aim is that the FM provider in the maintenance and operation of the hospital will keep it updated.

In the NRAH there is an aim but no requirement to use BIM for more than design and constructing the hospital. The aim is to create a legacy with the BIM-model that makes it possible for the FM to use it when they mature in to it. They try to collect as much information in to the model as possible.

Since they both are PPP projects the FM provider has been present throughout the planning of the buildings so the reason why Coor has more requirements to use BIM in the FM is difficult to answer. It could be a question of resource availability.

The two projects are quite similar in how they have applied BIM. They both use the BIM-model for estimating in procurement. They make data and personal analyses of different types based on the model, including solving issues with clashes. They follow the progress of the construction project with status level marking. The BIM-model on the project platform is a key to the communication in NKS and NRAH. The model can be reachable from site via mobile tablets.

7.1.2 The effects

The implementation of BIM has most effect on the Time and cost management, Communication management and also makes it easier to manage risks.

In Time and cost management, even if there is a difficulty in providing a return of investment of BIM in these two projects, the interviewees are all convinced that BIM has saved the project money and time. One can even question if these complex projects would be possible without the use of BIM. The investment of time and money because of BIM occurs in the design phase

that results in an increase price on the design. They will receive a much better quality product in and the client will save during the buildings whole lifecycle. Therefore the development of BIM in today's industry lies in the hands of the client, they have to see the benefits and require it in their projects. In the NKS the clients together with contractors drove BIM initially while in NRAH there was one contractor that said that this had to be done.

In the Communication management the BIM-model enables people to get an easy understanding of the building and the issues. Though there is a problem with getting the different disciplines software to collaborate. There is an issue with information loss and size of the model-files in today's collaboration tools.

The risk management benefits since it is easy to understand the design of the building one can find clashes and other mistakes in the model before the drawings go out on site.

7.1.3 How to increase the benefits

The industry needs time to develop tools and understanding to see the benefits on all levels and in all phases of the project. A way to measure the impact of BIM needs to be developed. Someone then need to demand BIM, most likely the client who has an overall interest in the building, they are the ones who will benefit the most from getting their building delivered in BIM.

One approximately needs two BIM-projects to see the benefits as a worker. And because BIM-projects are relatively new the industry needs some time to gain experience. The industry needs to become better at managing discipline. Only in these two projects they can already see a growing understanding that opens for new possibilities. In the production they are maturing in these large and complex projects and the FM are slowly structuring how they can use the BIM-model efficiently in the maintenance of the building.

Something that could help the development of BIM is if suppliers could provide digital contents of their products in a greater scale. This would save the designers in projects a lot of time and therefore the client money; it would also have an effect on the risk management because the information would come straight from the supplier without any middle hands and would be available for analysing earlier.

BIM creates a greater understanding within and between the different stakeholders throughout a buildings whole lifecycle. This is something that the whole industry would benefit from becoming more efficient and up to date with other similar industries.

7.2 Further research

During my time with this thesis there has been numerous times where I have wanted to reach outside my scope and research. Since this is a relatively small report these are some subjects that would require further research:

- How does the type of contract affect the implementation of BIM - that requires more investment in one end and benefits more in another?
- How can smaller construction projects benefit from BIM?
- What needs to be done and developed for the FM to use BIM more efficiently?
- How could BIM be more efficiently used on site?
- How can we make the BIM software collaborate easier? Whose responsibility is it to develop it?
- How could governments help speed up the spread of BIM?

8 References

8.1 Literature sources

Holme, I. M. & Solvang, B. K. (1997) *Forskningsmetodik: Om kvalitativa och kvantitativa metoder* (2nd Ed). Studentlitteratur, Lund, pg. 75-79

Independent economics (2012). *Economic Analysis of Building and Construction Industry Productivity: 2012 Report,* Master Builders Australia. Kingston. Ltd. pg.6

openBIM (2012). *OpenBIM - Programskrift*. Stockholm. pg. 2

Project Management Institute (2008). *A guide to the project management body of knowledge (PMBOK Guide) - Fourth Edition*. Pensylvania, USA. pg.5

Project Management Institute (2008). *A guide to the project management body of knowledge (PMBOK Guide) - Fourth Edition*. Pensylvania, USA. pg.6

Project Management Institute (2008). *A guide to the project management body of knowledge (PMBOK Guide) - Fourth Edition*. Pensylvania, USA. pg 13

Sveriges Byggindustrier (2011). *Fakta om Byggandet 2011.* Förlag, Stockholm, pg. 30

Statskontoret (2009:6). *Sega gubbar?* Statskontoret. Stockholm. pg. 97

Statskontoret (2009:6). *Sega gubbar?* Statskontoret. Stockholm. pg. 183

Stockholms läns landsting (2011). *Det ljusa sjukhuset – Nya Karolinska Solna i ord och bild*. Stockholm. pg. 1

8.2 Electronic sources

AssetWorks (2012), *Intelligent Workplace Management* (Hitting the headline article) [Online]. Available at: <http://www.assetworks.com/pdf/products/AiM_BIM.pdf>[Accessed 10 Jun 2013]

Australia Bureau of Statistics (2012), *1301.0 Year Book Australia 2012* (Hitting the headline article) [Online]. Available at: <http://www.abs.gov.au/ausstats/abs@.nsf/Lookup/by%20Subject/1301.0~20

12~Main%20Features~Construction%20industry~98>[Accessed 10 Jun 2013]

Australia Bureau of Statistics (2012), *1301.0 Year Book Australia 2012* (Hitting the headline article) [Online]. Available at: <http://www.abs.gov.au/ausstats/abs@.nsf/Lookup/by%20Subject/1301.0~2012~Main%20Features~Innovation%20activity%20of%20businesses~166> [Accessed 10 Jun 2013]

Autodesk (2013). *About BIM* (Hitting the headline article) [Online]. Available at: <http://usa.autodesk.com/building-information-modeling/about-bim/> [Accessed 10 Jun 2013]

buildingSMART (2012). *New Karolinska Solna University Hospital/ Patients come first in the new ultra moderna hospital* (Hitting the headline article) [Online]. Available at: <http://www.buildingsmart.org/standards/ifc/model-industry-foundation-classes-ifc> [Accessed 10 Jun 2013]

buildingSMART (2012). *The BIM Evolution Continues with OPEN BIM* (Hitting the headline article) [Online]. Available at: <http://www.buildingsmart.org/organization/OPEN%20BIM%20ExCom%20Agreed%20Description%2020120131.pdf> [Accessed 10 Jun 2013]

D.S. Thorpe, N. Ryan (2004). *Responding to the global issues: sustainability and innovation in the Australian Sme Residential building construction sector* (Hitting the headline article) [Online]. Available at: <http://eprints.usq.edu.au/2167/1/Thorpe_Ryan_Responding_to_global_issues.pdf> [Accessed 10 Jun 2013]

Ekonomifakta (2013). *Produktivitet i näringslivet* (Hitting the headline article) [Online]. Available at: <http://www.ekonomifakta.se/sv/Fakta/Ekonomi/Produktion-och-Investeringar/?awc=&gclid=CKCDgITv07cCFcKXcAodkC4Ajg> [Accessed 10 Jun 2013]

HYLC (2013). *Project Manager (HYLC – NRAH)* (Hitting the headline article) [Online]. Available at: <http://www.hansenyuncken.com.au/careers/positions-vacant?article=6891 > [Accessed 10 Jun 2013]

Messner, J. (2011). *Existing Conditions Modeling* (Hitting the headline article) [Online]. Available at: <http://www.bim.psu.edu/Uses/Existing_Conditions_Modeling.aspx> [Accessed 10 Jun 2013]

Messner, J. (2011). *Cost Estimation* (Hitting the headline article) [Online]. Available at: <http://www.bim.psu.edu/Uses/Cost_Estimation.aspx> [Accessed 10 Jun 2013]

Messner, J. (2011). *Phase Planning* (Hitting the headline article) [Online]. Available at: <http://www.bim.psu.edu/Uses/Phase_Planning.aspx> [Accessed 10 Jun 2013]

Messner, J. (2011). *Programming* (Hitting the headline article) [Online]. Available at: <http://www.bim.psu.edu/Uses/Programming.aspx> [Accessed 10 Jun 2013]

Messner, J. (2011). *Site Analysis* (Hitting the headline article) [Online]. Available at: <http://www.bim.psu.edu/Uses/Site_Analysis.aspx> [Accessed 10 Jun 2013]

Messner, J. (2011). *Design Reviews* (Hitting the headline article) [Online]. Available at: <http://www.bim.psu.edu/Uses/Design_Reviews.aspx> [Accessed 10 Jun 2013]

Messner, J. (2011). *Design Authoring* (Hitting the headline article) [Online]. Available at: <http://www.bim.psu.edu/Uses/Design_Authoring.aspx> [Accessed 10 Jun 2013]

Messner, J. (2011). *Engineering Analysis* (Hitting the headline article) [Online]. Available at: <http://www.bim.psu.edu/Uses/Engineering_Analysis.aspx> [Accessed 10 Jun 2013]

Messner, J. (2011). *Sustainability Evaluation* (Hitting the headline article) [Online]. Available at: <http://www.bim.psu.edu/Uses/Sustainability_Evaluation.aspx> [Accessed 10 Jun 2013]

Messner, J. (2011). *Code Validation* (Hitting the headline article) [Online]. Available at: <http://www.bim.psu.edu/Uses/Code_Validation.aspx> [Accessed 10 Jun 2013]

Messner, J. (2011). *3D Coordination* (Hitting the headline article) [Online]. Available at: <http://www.bim.psu.edu/Uses/3D_Coordination.aspx> [Accessed 10 Jun 2013]

Messner, J. (2011). *Site Utilization Planning* (Hitting the headline article) [Online]. Available at: <http://www.bim.psu.edu/Uses/Site_Utilization_Planning.aspx> [Accessed 10 Jun 2013]

Messner, J. (2011). *Construction System Design* (Hitting the headline article) [Online]. Available at: <http://www.bim.psu.edu/Uses/Construction_System_Design.aspx> [Accessed 10 Jun 2013]

Messner, J. (2011). *Digital Fabrication* (Hitting the headline article) [Online]. Available at: <http://www.bim.psu.edu/Uses/Digital_Fabrication.aspx> [Accessed 10 Jun 2013]

Messner, J. (2011). *3D Control and Planning* (Hitting the headline article) [Online]. Available at: <http://www.bim.psu.edu/Uses/3D_Control_and_Planning.aspx> [Accessed 10 Jun 2013]

Messner, J. (2011). *Record Model* (Hitting the headline article) [Online]. Available at: <http://www.bim.psu.edu/Uses/Record_Model.aspx> [Accessed 10 Jun 2013]

Messner, J. (2011). *Building Maintenance Scheduling* (Hitting the headline article) [Online]. Available at: <http://www.bim.psu.edu/Uses/Building_Maintenance_Scheduling.aspx> [Accessed 10 Jun 2013]

Messner, J. (2011). *Building System Analysis* (Hitting the headline article) [Online]. Available at: <http://www.bim.psu.edu/Uses/Building_System_Analysis.aspx> [Accessed 10 Jun 2013]

Messner, J. (2011). *Asset Management* (Hitting the headline article) [Online]. Available at: <http://www.bim.psu.edu/Uses/Asset_Management.aspx> [Accessed 10 Jun 2013]

Messner, J. (2011). *Space Management and Tracking* (Hitting the headline article) [Online]. Available at: <http://www.bim.psu.edu/Uses/Space_Management_and_Tracking.aspx> [Accessed 10 Jun 2013]

Messner, J. (2011). *Disaster Planning* (Hitting the headline article) [Online]. Available at: <http://www.bim.psu.edu/Uses/Disaster_Planning.aspx> [Accessed 10 Jun 2013]

NBS (2012). *What is the National BIM Library?* (Hitting the headline article) [Online]. Available at: <http://www.nationalbimlibrary.com/Help/BIM-Library> [Accessed 10 Jun 2013]

Northumbria University, Ryder (2012). *bimacademy* (Hitting the headline article) [Online]. Available at: <http://collab.northumbria.ac.uk/bim2/?page_id=500<text> [Accessed 10 Jun 2013]

SA Health (2012). *The new Royal Adelaide Hospital* (Hitting the headline article) [Online]. Available at: <http://www.sahealth.sa.gov.au/wps/wcm/connect/public+content/sa+health+internet/health+reform/the+new+royal+adelaide+hospital> [Accessed 10 Jun 2013]

SA Health (2012). *Construction and timeline for the new Royal Adelaide Hospital* (Hitting the headline article) [Online]. Available at: <http://www.sahealth.sa.gov.au/wps/wcm/connect/public+content/sa+health+internet/health+reform/the+new+royal+adelaide+hospital/construction+and+timeline+for+the+new+royal+adelaide+hosptial> [Accessed 10 Jun 2013]

Scott, M. (2012). *What is BIM? A video explaining the technology* (Hitting the headline article) [Online]. Available at: <http://www.youtube.com/watch?v=QElAdXH_rQU> [Accessed 10 Jun 2013]

Skanska (2012). *New Karolinska Solna University Hospital/ Patients come first in the new ultra moderna hospital* (Hitting the headline article) [Online]. Available at: <http://group.skanska.com/en/campaigns/125/new-karolinska-solna-university-hospital/> [Accessed 10 Jun 2013]

Trochim, William M.K. (2006). *Research Methods Knowledge Base; Deduction & Induction* (Hitting the headline article) [Online]. Available at: <http://www.socialresearchmethods.net/kb/dedind.php> [Accessed 10 Jun 2013].

Wong, J. Yang, J. (2010). *Research and application of BIM in the AEC industry: a review and direction for future research* (Hitting the headline article) [Online]. Available at: <http://eprints.qut.edu.au/38333/1/38333.pdf>

[Accessed 10 Jun 2013]

WSP (2013). *BIM – changing our industry* (Hitting the headline article) [Online]. Available at: <http://www.wspgroup.com/en/wsp-group-bim/BIM-home-wsp/what-is-bim/> [Accessed 10 Jun 2013]

8.3 Interviews

(AH) Hallworth, A. (2013) Interviewed by Jenny Rydén [Phone interview], Sydney, 9 may 2013, 10:00 AM

(MH) Hooper, M. (2013) Interviewed by Jenny Rydén [e-mail interview], Sydney, 23 april 2013

(MK) Kastell, M. (2013) Interviewed by Jenny Rydén [Phone interview], Sydney, 7 may 2013, 00:00 AM.

(CP) Penn, C. (2013) Interviewed by Jenny Rydén [Phone interview], Sydney, 9 april 2013, 11:30 AM

(UP) Persson, U. (2013) Interviewed by Jenny Rydén [Phone interview], Sydney, 12 april 2013, 00:30 AM

(PS) Sundström, P. (2013) Interviewed by Jenny Rydén [Phone interview], Sydney, 5 april 2013, 11:00 PM

(GQ) Qvarnström, G. (2013) Interviewed by Jenny Rydén [Phone interview], Sydney, 10 april 2013, 5:00 PM