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STUDY OF THE IMPLEMENTATION PROCESS OF BIM IN CONSTRUCTION PROJECTS

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ABSTRACT

The AEC-industry has been lagging behind other types of production industries in terms of productivity development for the last 40 years. The reason for this has been described as to be a combination of the collaborative needs in performing construction projects combined with the fragmented nature of the AEC-industry. Building information modelling (BIM) has been presented as a way of addressing these issues and thereby improving productivity in construction projects.

The adoption of BIM has been slow and many barriers hindering widespread adoption of this technology have been revealed. There are however no single barrier that could be solved individually in order to enable more extensive BIM adoption. These barriers are hindering many different aspects of effective adoption of BIM.

When compared to traditional 2D CAD systems, BIM is a more efficient way of handling information connected to the project or the building. Adoption of BIM enables changes in work processes that can streamline the performance in construction projects.

Adoption of BIM is not only a change in technology; there is a need for substantial changes in work processes in order to make improvements to productivity. BIM is a tool to improve processes in order to reach certain goals, not a goal in own right.

In this thesis I examine how BIM has been adopted in two different construction projects. The research aims to develop the understanding of the barriers hindering BIM adoption in order to make it more accessible for the AEC-industry.

I. INTRODUCTION

1.1 Introduction / Background

The real estate and construction industry is one of the world‟s larger industries but also one of the most fragmented. The characteristic view of the industry is of a brought together multidisciplinary group in a unique project facing great coordinating issues (Isikdag et al. 2007). Advances in information and communication technology (ICT) have been put forward as a tool to deal with these coordination issues in order to improve the industries historically low productivity (Johnson and Laepple 2003).

During the last three decades the construction industry has seen drastic improvement of the use of IT (Fisher et al. 2006). The latest and most promising in these developments is the use of Building information modelling (BIM) (Eastman at al. 2011). BIM can be described as a tool that enables storage and reuse of information and domain knowledge throughout the lifecycle of the project (Vanlande and Nicolle 2008). Therefore BIM has a main role of coordinating and integrating the exchange of information and knowledge between different disciplines and phases within the project.

The use of BIM in a construction project both has the potential benefit of improving product quality, and enabling more sustainable designs of buildings (Eastman et al. 2011).

Even though the economic and environmental benefits of BIM is widely acknowledged (Eastman et al. 2011; Howell and Batcheler 2005; Azhar et al. 2008; Fischer and Kunz 2006; Yusuf et al. 2009), the adoption of this new technology has been slow (Bernstein and Pittman 2005). This thesis aims to develop the understanding of the barriers limiting the implementation of BIM in the construction industry by studying different project participants‟ expectation of BIM.

1.2 Problem statement

The AEC-industry has a historically low increase of productivity when compared with other industry. BIM has been introduced by many as a way of addressing this problem, but even while the development of BIM has continued for many years the adoption rate is still slow. There are currently a lot of research developing theories on why, focusing on different barriers limiting the usefulness of BIM or limiting the ability to adopt BIM in construction projects. How these different theories interact is however not very well documented. There is a need to develop the understanding of how these barriers combine and in what way they can be bridged. There is also no clear consensus of which actor, if any, that should drive the development and adoption of BIM in order to address this low productivity rate.

1.3 Purpose

This thesis analyses the underlying barriers which hinders BIM adoption in the AEC-industry. The purpose of the research is to develop the understanding of the decision making process regarding BIM in a construction project. By understanding the implementation process of BIM, the cause of its slow adoption rate can be further examined.

1.3.1 Research question

I order for achieve the purpose of this thesis I have worked with the following research question:

- How is the decision regarding BIM taken in a construction project?

This research question aims to reveal how the process of BIM adoption is initialized in construction projects. I will survey the early phases of a construction project and my research hopes to reveal the following:

- How the decision regarding BIM was made, what benefits and barriers was deemed most important?
- Which actors that were involved in this decision?
- How accurate the different actors understanding of BIM are?
- If there were a consensus regarding the decision or if single individuals drove the adoption process?
- How barriers to BIM adoption have been addressed in the project?

This will enlarge the empirical material supporting the different theories explaining the slow implementation on BIM in the AEC-industry today.

1.4 Delimitation

The scope of the thesis involves how BIM came to be adopted in specific cases studied, how the decision was made and by whom and how the project team tries to meet the barriers connected with a BIM implementation.

If the adoption of BIM has been successful or not cannot be analysed in the studied cases because of the early staged in their progress, and is only indirectly interesting for achieving the purpose of the thesis. The general benefits of BIM have been analysed in many other studies and I find those results sufficient for my analysis.

1.5 Reading guide

Before reading the whole theses a brief explanation of the layout of the thesis might be beneficial enabling better understanding of the research and the findings.

The *theory* chapter is divided into two different parts; the first one describes BIM as a concept and elaborates around why the issue of BIM is of interest. The second part describes different barriers to BIM adoption and why these barriers are issues of concern.

The *empirics* chapter describes two projects in which BIM has been used. These projects serve as practical examples of how the barriers can be bridged. BIM has been adopted or is planned to be adopted quite differently in these two projects.

The *analysis* combines the findings in both the "theory" and "empirics" chapters and elaborates on how the issues and barriers described by other researchers have been addressed in the cases studies.

The *conclusion* chapter is then a summary of the discussion made in the *analysis* chapter and drawing conclusions based on the questions described in the *introduction* chapter.

II. METHOD

This chapter describes how I have conducted my research in the thesis, the methods and techniques used in the collection of data. Here threats to the validity and reliability to the results and conclusions are also present together with how ethics have been addressed throughout the research.

2.1 Research design

The research design is the general plan for how the empirical research should be related to the conceptual research problem. It provides a plan for how and what data should be collected and how the results should be analysed. The chosen research design will influence the type and quality of the collected empirical data. (Ghauri and Grønhaug 2010)

My choice of research design is exploratory research. The research problem in this thesis is well understood, namely the slow implementation of BIM. The goal of my research is to develop the understanding of the barriers slowing down the adoption of BIM in the AEC-industry. The research also wants to examine how different barriers revealed in earlier research affect a specific project and which of them have actually been deemed as most problematic. This research design is suitable to explore the impact of different barriers and how they have affected the decision to either adopt BIM or continue using the traditional work processes.

The goal of this research design is to develop the underlying theory of how the different barriers hinders the adoption of BIM in the AEC-industry.

2.2 Reasoning - Inductive and deductive

There are two different ways of establishing what is true or false and ways of drawing conclusions. These ways are induction and deduction. Induction is based on empirical evidence while deduction is based on logic. (Ghauri and Grønhaug 2010) - 11 -

Induction – This way of reasoning draws general conclusions from empirical observations. Inductive research progresses from observations → findings → theory building. Findings are added to the existing knowledge, literature or theories, to improve these theories. The outcome of this research is theory. Generally this research is associated with the qualitative research type. When following this type of reasoning it is however important to know that the inductive conclusions are never absolutely reliable. These conclusions are based on empirical observations and even in a large number of such observations you can never be sure that any interesting results are missed. (Ghauri and Grønhaug 2010)

Deduction – This way of reasoning draws conclusions based on logic. The researcher builds hypotheses from existing knowledge, which can be tested trough empirical studies and be accepted or rejected. Generally this type of research is associated with quantitative research. (Ghauri and Grønhaug 2010)

I have chosen to mostly incorporate the inductive reasoning in this thesis. This type of research will enable me to draw conclusions from collected data and enlarging the understanding of the barriers limiting the adoption of BIM. On the other hand I have used deductive reasoning analysing which barriers affecting the different projects and adapted my case-studies and interviews thereafter.

2.3 Qualitative and Quantitative research methods

The two basic groups of research methods are: qualitative and quantitative. The difference between these research methods is the procedure in which data is collected. The choice of method is based on the research design chosen. (Ghauri and Grønhaug 2010)

My choice of exploratory research makes the qualitative research method most suitable. This research method is suitable when emphasising on the understanding on the underlying problem (Ghauri and Grønhaug 2010). - **2.4 Literature review**

The literature review is aimed to establish a theoretical understanding of the concept of BIM and the barriers limiting its adoption. It has been used in two stages, first to assure my understanding of the prior knowledge in the subject, and secondly to be a comparison for the empirical data. The areas of interest for my literature review are: BIM as a concept, benefits of BIM and barriers to BIM adoption. The sources have mainly been books and articles.

2.5 Empirical data

For primary data I have chosen to use two case-studies and to supplement them with interviews to deepen my understanding of the projects.

2.5.1 Case-studies

There are several case-studies done on projects where BIM has been implemented. They provide good secondary data for the analysis in the thesis. These cases are generally not located in Sweden however, and might therefore not be representative of the conditions is this country. The cases studied are the following:

- *KTH Campus Utbildningshus* – “Akademiska Hus” is currently planning new facilities at the KTH campus at “Valhallavägen”. This project will implement BIM and therefore suite as a good case to study. This project is in the initial stage, and therefore it should be interesting to see how issues with the BIM adoption are addressed and how the decisions were made.
- *Nya Karolinska Solna (NKS)* – The hospital “Nya Karolinska” is currently constructed. In this project there are high expectations regarding the use of BIM and this will continue through the projects lifecycle. Therefore this project serves as another good case to study when analysing how BIM can be adopted in a Swedish context. This project has progressed much further than the project in KTH Campus and therefore other issues will have been found and addressed which will be of interest to the research.

The information for the case-studies will be gathered mostly by interviews of people connected with usage of BIM in the project. Information will also be gathered in protocol notes and similar sources.

2.5.2 Interviews

The main role of interviews in the research is to supplement the case-studies and provide deeper understanding of how the project processes have been affected by BIM. The people I have interviewed have been directly connected with the BIM adoption in the respective projects and have therefore been of interest. The interviews have been of a semi-structured type with much freedom to elaborate both on the concept of BIM and how it affects or is expected to affect the project processes.

2.6 Validity and reliability

The validity and reliability of the collected data in the thesis will have an impact on its value. Without correct and repeatable results its value decreases rapidly (Ghauri and Grønhaug 2010). As discussed in the "case-studies" section, empirical data from other countries might not be valid in Sweden. This has to be taken into account when interviews and the case-studies are done and analysed; the research should try to determine if the results in the international studies can be repeated in Sweden and thereby determine its reliability.

Because the cases studied in the research are not completed and its BIM system is under development there can be validity problems in the results from the projects. Results can mirror expectations and hopes of future usefulness rather than actual results. I will use interviews to try to avoid this by analysing how decisions have been made and what they are based upon.

2.6.1 Validity threats

This thesis might suffer from the following validity threat:

Selection bias – This thesis will suffer from selection bias because the analysed cases cannot be chosen randomly. In addition to this the subjects might be biased because of their choice to use BIM in their current project. This choice can have an impact on the interviewee‟s views on the potential usefulness of BIM, and make them generally positive. Because the cases studied are not completed, unbiased quantitative analyses cannot be done in this stage to verify the results.

2.7 Research ethics

It is important to have research ethics in mind. The research should not cause embracement or in any way harm any participating individuals. The published thesis will also be available for all interested parties which makes everything it contains public. To address this issue I have made sure that the interviewees have been aware of what my research aims to achieve and how I want to use their contribution. Simultaneously the contribution to my research is unlikely to be of embarrassing or harmful nature to any individual as the subject is not very sensitive. Anyhow, I have decided to make all individuals anonymous in regards to their names and only presented them as their professional roles in the projects. The interviewees themselves are not of interest to the research but rather their professional roles in the different projects.

III. THEORY

In this chapter the theoretical background to BIM in the AEC-industry is presented. The goal is to, first elaborate around the concept BIM and secondly to collect different theories on which barriers have the greatest impact on the willingness and effectiveness of BIM adoption in the AEC-industry.

3.1 Background to BIM

3.1.1 BIM as a concept

The basic theory behind Building information modelling is well described by Thompson and Miner (2007), in that; if all relevant data connected to a project were stored in a single online system, the project could be executed in a virtual environment first. When dimensions of time (scheduling) and costs are added to the model

(ICITTESE-17)
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this enables easy cost-time-benefit analysis of different options almost instantaneously. (Thompson and Miner 2007)

When developing such models for the entire project, more stakeholders, than it is practical today, can be included in the early phases of a project. These stakeholders can inject their business- and engineering knowledge into the design of the facility, its schedule and its organisation; thereby improving coordination in all phases of the project (Fischer and Kunz 2006). The resulting BIM model, which is a data-rich, object-oriented parametric representation of the facility, will serve as a repository for data which can be extracted and analysed to suite all different users‟ needs throughout the buildings entire lifecycle (Azhar et al. 2008).

3.1.2 Different levels of BIM

Currently there is a lack of a clear definition in regard to what BIM actually is (Howard and Björk 2008). There are many different levels to what professionals define as BIM and this makes discussions regarding BIM somewhat unclear. Many different organisations have tried to define BIM but there is a lack of consensus, many aspects are similar in regards to the model but the level of how BIM affects the work processes differs (Isikdag, et al. 2007).

In this thesis the description of BIM used by the NBIMS (National Building Information Modelling Standard) is used as a reference point in my research because it covers more than just the model. NBIMS describes BIM as the following:

Building information modelling is a new way of creating, sharing, exchanging and managing the information in the project throughout the buildings entire lifecycle. In this BIM can be categorised into different parts containing (NBIMS 2007, in Isikdag, et al. 2007):

Product – An intelligent representation of the building. It is intended as a repository for information to be used by the owner or operators and maintained throughout the buildings entire life-cycle.

Collaborative process – Covering business standards, automated process capabilities and interoperability for sustainable information usage.

Many definitions of BIM address it as a single model as the repository for the information (Isikdag, et al. 2007). This single model is however seen as cumbersome by many professionals and it will need to be used together with other type of data storage (Howard and Björk 2008). It might be more practical to coordinate through a single database linked to the model and keep the geometrical model simple (Howard and Björk 2008). The single building information model has been a holy grail but it is doubtful if it will be achieved or not (Howard and Björk 2008).

There are a great variety of different types of companies in the AEC-industry, with different size, type of profession, experience with BIM, and so on. To make a business case reliable it should be developed to accomplish specific objectives taking the particular requirements and characteristics of the company in consideration. It is not possible to make a typical business process for the implementation of BIM. It is also possible that a single company should develop more than one business case, each based on different scenarios. For example, there might be different level of model sharing between the consultants in different projects. Depending on the level of implementation of the possibilities with BIM the initial cost will vary, with highest costs following high level of implementation. It is however suggested that organisations will recover quickly with a positive ROI as their performance will improve dramatically. (Aranda-Mena et al. 2009)

3.2 Potential benefits with BIM

The possible economic benefits and improvement of productivity with successful implementation of BIM is well acknowledged and gradually better understood within the AEC-industry (Bernstein and Pittman 2005). Several studies have made conclusions regarding the advantages and possible benefits with this new technology in comparison to traditional 2D CAD. For example:

"BIM is certainly viable and offers many realizable advantages over CAD" - Howell and Batcheler (2005)

"As the use of BIM accelerates, collaboration within project teams should increase, which will lead to improved profitability, reduces costs, better time management and improved customer/client relationships"

- Azhar et al. (2008)

"Building information models supports the exchange of data between software to speed up analysis cycle times and reduce data input and transfer errors"

- Fischer and Kunz (2006)

BIM can deliver tremendous benefits, but doing so requires a departure from traditional ways of working.

- Arayici et al. (2009)

BIM is presented by many as a way of increasing the historically low productivity in the AEC-industry. According to Kiviniemi (2013) there are studies showing that the AEC-industry has much worse development of productivity compared to other production industries, some even show that its productivity has actually decreased during the last 40-years.

This development stems from poor information flow and need for redundancy. By improving the management of information in construction projects and enabling more collaboration within the extremely fragmented AEC-industry, BIM is a way of addressing these issues. BIM is however not a goal in itself but rather a tool to enable this higher productivity. (Kiviniemi 2013; Eastman et al. 2011)

As well as improving productivity during the project itself BIM has been presented as a tool to increase performance after the project, in the facilities management phase. According to Ding et al. (2009) the three aspects most beneficial with adopting this new technology are: Digitalization, procurement and benchmarking. Ability to use the model to support these three aspects will improve the facilities management system and make it more sustainable. It will provide better productivity and efficiency of both the facilities management team and the organization as a whole; also it increases the return on investment for the owner. (Ding et al. 2009)

Most facilities management systems do have access to all available information. These systems also have problems with capturing potentially useful information from the facility and its linked activities in an integrated reusable way. BIM can be used to support the facilities management system by serving as an information storage platform throughout the lifecycle of the project, where it can serve as an „as commissioned‟ or „as maintained‟ model rather than the traditional „as built‟ drawings. (Ding et al. 2009)

3.3 Slow adoption

Even though the potential benefits are well documented, both in terms of improved productivity, together with many other potential benefits, - 19 -

the adoption of BIM is still slow in the industry (Gu and London 2010; Azhar et al. 2008; Bernstein and Pittman 2005).

The AEC-industry is traditionally slow in adopting new technology and BIM will have great effect on how the work processes look in the projects. But for BIM to be adopted successfully to improve productivity there is a need to change these work processes. The fragmented industry is a problem here because this change cannot be adopted by single actors but must instead affect all involved actors. Adoption of BIM will emphasise on integration, collaboration and innovation connected with large cultural changes in the industry. (Kiviniemi, 2013)

3.4 Barriers to BIM adoption

There are problems when implementing BIM in the very fragmented AEC-industry and this is connected with many different barriers hindering effective adoption. Gu et al. (2008) presents a way of categorizing relevant factors connected to the slow BIM adoption in the AEC-industry. These categories are; in terms of Product, Process and People. The reason for the slow BIM implementation is not simply one single issue, but rather the combination of several issues (Kiviniemi, 2013; Gu et al. 2008). In order for BIM to be adopted on a border front in the AEC-industry all of these issues must be considered.

3.5 Barriers linked to the BIM product

Many issues limiting the adoption of BIM in the AEC-industry is connected with the BIM tools and their development. These issues are mostly aspects of poor interoperability between different BIM programs and tools, but this is not the only areas of concern. Currently the user's demands on BIM are not always met by technical possibilities with BIM as it is currently supplied.

3.5.1 Interoperability

Construction projects require good collaboration and information exchange between all involved actors due to the collaborative nature of the industry. Traditionally this exchange was made in the form of drawings and documents, when moving to adopt BIM new requirements are introduced to ensure effective information exchange. BIM is not only a tool in the design phase of the project, but rather an interface for information exchange between different actors and phases in the project. Currently the different actors are often using different tools, either from different vendors or specialized for their business. Such difference in BIM tools presents challenges for information exchange between the different actors because of inadequate or lacking interoperability (Steel et al. 2012).

The development of BIM tools have progressed in the pursuit of solutions for different professions. This process resulted in different programs that do not interface well with each other or with advanced project management tools. The two largest challenges for technology developers in regards to BIM have ended up being interoperability in existing BIM systems and creation of multi accurate models to fulfil different purposes. (Thompson and Miner 2007)

The Industry Foundation Classes (IFC) defined by the "building SMART alliance", is the accepted standard for BIM models. IFC is an ambitious attempt to achieve model-based interoperability. It covers a wide range of modelling information, not limited by the geometry of the objects, but also metadata related to other aspects of the building. (Steel et al. 2012)

When analysing the level on interoperability in IFC, Steel et al. (2012) consider it in four different levels.

File level interoperability - This covers the ability for different tools to successfully exchange files.

Syntax level interoperability - This coves the ability for different tools to successfully parse files without errors. This also covers the ability for different tools to interoperate without errors.

Visualization level interoperability - This covers the ability for different tools to correctly visualise the exchanged model.

Sematic level interoperability **-** This covers the ability for different tools to come to the same understanding of the meaning of a model being exchanged.

The analysis by Steel et al. (2012) came to the conclusion that IFC has so far achieved relative success in providing interoperability in the file and visualisation levels within a subset of domains. This is most notable within architectural design. In situations demanding sematic interoperability it still faces challenges however. That is also the case when its use is broadened to include more sub-domains. (Steel el al 2012)

The problem with interoperability within the construction industry is the width of the domain itself, different projects can range from anything from a simple one family house to large airports. This breadth has been problematic to IFC and its interoperability because no one tool implements all of its language (Steel el al 2012).

Because of the fragmented and collaborative nature of the AEC-industry interoperability is an important issue. BIM has many viable advantages over CAD, but the ability to share intelligent building information is critically important (Howell and Batcheler 2005). In order to maximise many of the benefits BIM enables in regards to productivity and design quality the challenges with interoperability must be addressed (Steel et al. 2012).

3.5.2 Different views on BIM

Research by Gu et al. (2008 and 2010) has concluded that the views on what BIM is depend a lot on the particular actor. Both the profession and size of the firm are factors of importance in regard to this difference of perception on what BIM is and how the actor wants to use it. Generally, large firms who will more likely be involved in large projects will prefer tools with greater flexibility in customising project environments, smaller firms, on the other hand, are more likely to prefer more intuitive project environments. (Gu et al. 2008; Gu and London 2010)

The professionals from the AEC-industry generally want BIM to incorporate all capabilities of CAD to be able to continue benefit from these which use they have maximised over the last decades. But there is also an interest in the new capabilities that BIM tools have the potential to provide. In other words they want BIM to contain new features while not removing old capabilities (Khemlani, 2007).

Expectations on BIM also vary depending on the profession of the user. Design professionals view BIM as an extension on CAD, while project managers and contractors see BIM as a more intelligent document management system suitable for extracting and analysing data directly from a CAD package. Even though BIM developers aim to integrate both of these aspects, the survey of Gu et al. (2008) suggests that current BIM applications are not completely mature to satisfy either of the two. This results in a situation where the different actors have different expectations and demands on the new technology and no joint understanding of what BIM is. (Gu et al. 2008)

Currently most studies have emphasised BIM as an enhancement to current CAD technology while not emphasising its document management qualities (Gu et al. 2008). Simultaneously the development for BIM to support facilities management is lagging behind the development of BIM in the design stages of a project (Eastman et al. 2011). This development has inhibited the interest of non-design professions towards the adoption of BIM technology (Gu et al. 2008). Gu et al. (2008) further argues that the user-centric development of BIM has to be more inclusive since the successful BIM adoptions demands collective participations and contribution from all project participants.

(ICITTESE-17)
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3.5.3 Poor match with the user's needs

In a quantitative survey among architects by Tse et al. (2005) it was revealed that a large part of the respondents did not find the tools in BIM to satisfy their needs, others simply stated that BIM is "not easy to use". The problems were largely connected with free form object that was hard or not possible to customize. With the current development of BIM, however, such object customizations are now possible but require training and an extended model construction time. This factor was believed by Tse et al. (2005) to be a major barrier for BIM adoption, especially in more complex projects. Other connected results regarding BIM shortcomings included: "lack of table customization", "not enough objects", "speed of system is not fast enough" and "text and dimension compatibility with AutoCAD". (Tse et al. 2005)

3.6 Barriers linked to the BIM process

Adoption of BIM will require change of current work practice (Gu and London 2010). New business processes have to be adopted and the roles of different actors will be affected. Legal issues with responsibility and ownership of the BIM model are also topics needing new processes to be effectively solved. These issues are categorized in this section.

3.6.1 Changing work processes

The implementation of BIM can provide great benefits, this change however; require a substantial change of the traditional ways of working (Arayici et al. 2009). The basic BIM concept of a single integrated model for the whole project life-cycle needs to be developed in a collaborative setting where multiple project participants are able to contribute (Gu and London 2010). Simultaneously efficient multidisciplinary project groups supported by BIM require change in the roles of the clients, architects and contractors, and new contractual relationships and a reorganised collaborative process must be created (Rizal 2011).

The new life cycle approach to building projects, that BIM enables, require a more integrated collaboration approach. In order to assure sustainability in the project, end-users, facility managers, contractors and specialist contractors are needed in the planning and design phases of the project. This reflects the development of changing roles of the project participants and new procurement methods following with BIM implementation. (Rizal 2011)

For BIM to be successful, collaboration from all different stakeholders are needed, to insert, extract, update or modify information in the BIM model in the different stages in the facilities life-cycle. This is done to support and reflect the roles of all different stakeholders in the model. Optimally the model can become a virtual representation of the facility that can be handed over from the design team to the contractor to sub-contractors and to the client. As a central model for all stakeholders in the project the BIM model will evolve as the project progresses. Suggested design solutions or changes can be evaluated and compared to the requirements by the client during the whole project. The use of BIM to support cross-disciplinary and cross-phase collaboration opens for new dimensions in the roles and relationships between the project-participants. (Rizal 2011)

The most important issues according to Rizal (2011) are:

- The new role of model manager
- Agreement on access right and intellectual property right
- The liability and payment arrangement according to the type of contract in relation to the integrated procurement
- The use of international standards

Adoption of BIM will have large effect on the work processes and traditional roles in the industry. This adoption will not be easy for actors uncomfortable with change and firms implementing BIM will have to address issues with how workflows should be redesigned, how staff should be assigned and how to distribute responsibilities (Arayici et al. 2009).

3.6.2 Risks and challenges with the use of a single model

Following the substantial change in work practice associated with BIM causes many risks. When all different stakeholders are inserting, extracting, updating or modifying the information in the BIM model there will be questions regarding who will be able to do and be responsible for the editing of data in the model. There is also a lack of developed standards for who will be responsible for inaccuracies in the model. Responsibility for updating the model and ensuring that it is accurate comes with a great deal of risk. (Thompson and Miner 2007)

Risks following use of the model for purposes not intended are also a problem. If for example information regarding the concrete base-structure is added and later used for procurement of a curtain wall, which it might not be suitable for, the results could be grave. To address this issue models are now often labelled with "for reference only" or another disclaimer of accuracy because designers are not willing to take on risks with warranting their use. The more disclaimers of this type, the less likely the other project participants are to use this new technology and designers will have more problems with receiving the additional compensation for the possible efficiency savings associated with BIM. (Thompson and Miner 2007)

The speed by which an electronic design can be modified and changed is connected to both opportunities and risks. Questions regarding when the design is finalized for contractors bidding on it, or does fast changes in design with instantaneous notice expect equally fast knowledge and agreement of the changes? In order to avoid disagreements, a definition of the project design and a protocol for how building information should be shared must be created, otherwise all project participants might not be on the same level when discussing what has been offered and what has been accepted. (Thompson and Miner 2007)

3.6.3 Legal issues

With BIM as a new type of construction document, one of the first issues needed to be addressed is the ownership of the model. The project owner who is paying for the design might feel entitled to own the model, but other project team members might have provided property information and such information needs to be protected as well. The question of ownership of the model must be solved uniquely in every project because of the different circumstances. Connected to these issues, discussions regarding licensing can arise when project team members other than the owner or the design team contribute information which is integrated in the model. (Thompson and Miner 2007)

Issues regarding contractual responsibilities for inaccuracies in the BIM model will also be an issue which needs to be addressed. The process of updating BIM data and assuring accuracy entails a great deal of risk. According to Thompson and Miner (2007) concerns of indemnities for BIM users and offers of limited warranties and disclaimers of liability for the design team are essential negotiation points that have to be addressed before BIM technology can be adopted.

The ability to extract fast and easy cost calculations and schedules from a model which are added dimensions of time and cost will enable more efficient estimations. With this come issues with responsibility for interoperability between the various programs being used. When data is delivered in the same software, integration between different actors can be fluid. When data is lacking or delivered through different scheduling or costing programs with lacking interoperability, a project team member must re-enter and update the model to include the new data. According to Thompson and Miner (2007) the responsibility for the accuracy and coordination for cost and scheduling data must be contractually addressed.

3.6.4 Transactional business process evolution

How BIM can be used to enhance collaboration trough changing roles of the client, architect and contractors is a widely researched field. However, the management of this collaborative process and the implementation of BIM as ICT support are still suboptimal in practice. In case-studies by Rizal (2011), it was revealed that contractual limitations to the roles and responsibilities of the project participants in the traditional procurement system hindered the needed change in roles. In order to make the BIM implementation more efficient the needed changes in the respective roles should be introduced already in the procurement stages in the project (Rizal 2011).

Gu and London (2010) argue that one of the most critical process issues needed to be addressed is, that projects will not succeed if the need for change in business models are not solved in a way to suit the varied industry needs. Depending on how the BIM model is managed and maintained additional legal agreements might be needed to ensure data security and user confidence (Gu and London 2010).

The new technology enables new process possibilities for designers and constructors exceeding the norms of practice and well understood - 27 -

business protocols. Bernstein and Pittman (2005) present the several issues in need of address when evolving the current transactional business processes into new standards. (Bernstein and Pittman 2005)

With the implementation of BIM the flow of information will improve and the different processes can be better connected, but it will not solve the business challenges. The different roles in the building supply chain are connected with certain obligations, risks and rewards. With the implementation of BIM these work processes changes and that will affect these factors as well. Before this new technology can be fully adopted these basic business terms must be defined across the enterprise. (Bernstein and Pittman, 2005; Gu and London, 2010)

Obligations

Which tasks are allocated to each actor? What needs to be delivered to complete these tasks? What information should be exchanged to meet the demands by the other actors? Defining what specific information the different actors are responsible to exchange will both define responsibilities and limiting the need for all actors to interoperate with all data in the model. Defining responsibilities are both relevant for legal warranties and assuring the quality of the produced information. Limiting the need for all actors to address all data in the model will decrease the workload, and assure that only actors with competence on the given topic are involved. (Bernstein and Pittman 2005)

Risks

The change in how documents are produced will affect how the boundaries and responsibilities are given. When the design information is produced in collaboration among many actors, determining responsibilities for inaccuracies can be problematic. With this follows problems when assigning risks. How can the risks be assigned fairly? Either could design decisions be tracked to their origins or it could be argued that a project with open collaboration imply equally shared responsibility. (Bernstein and Pittman 2005)

Rewards

The rewards in a project must always be connected with the risk distribution. When risks are equally shared, shared rewards must follow. This means that some of the savings for the owner, due to higher productivity, must be shared with the participating project members. The market forces will eventually determine a new baseline for compensating the different actors. Until that happens, the value of digital models as deliverables that follow the project its entire life-cycle must be discussed. It is argued by Bernstein and Pittman (2005) that rewards are the primary driver when implementing new technology and higher efficiency is not sufficient to change business behaviour. (Bernstein and Pittman 2005)

These three business issues must be addressed and defined in parallel before BIM can be widely adopted by the AEC-industry. Early adopters of BIM have suggested alternatives for how these issues could be addressed. Such projects are generally highly collaborative and where the design is developed with full integration with all sources of information. In those project risks are by default distributed among all the actors. As the value of this type of collaborative processes becomes apparent and projects are completed on schedule and budget, actors offering BIM solutions will command larger fees and share the risk distribution in their contracts. (Bernstein and Pittman 2005)

3.6.5 Lack of demand and disinterest

It is suggested by Tse et al. (2005) that one major reason for why architects are not changing towards BIM is the lack of demand from clients and other project team members. This connected with that a majority of architects agreed with the statement "existing entity-based CAD systems could fulfil their drafting and design needs" in their survey. Simultaneously, the same study indicated that architects would be more inclined to adopt BIM if they could see a large gain in productivity in contrast to conventional CAD systems as well as downstream applications of the building information. (Tse et al. 2005)

The study by Gu et al. (2008) showed that "The success of BIM adoption lies in the collective participation and collaboration from all the stakeholders in a building project". Further their study have shown that lack of awareness, focus on BIM as an advancement to CAD and relative underdevelopment of BIM‟s document handling capabilities have inhibited the interest by non –design disciplines within the AEC- industry (Gu and London 2010).

Because of the insufficient number of case-studies showing the potential financial benefit of BIM the AEC-industry is generally not very interested in investing towards the change in technology (Yan and Damian 2008). Simultaneously, some clients who are successfully using BIM may not have an interest in sharing their knowledge (Howard and Björk 2008). Several of the leading property owners changing towards BIM are public organisations with a duty to publish their knowledge to support the change (Howard and Björk 2008). More cases showing the benefits with BIM implementation will help convince other property owners, contractors and consultants that they are not being used as test subjects in purely experimental projects (Howard and Björk 2008).

3.7 Barriers linked to the individuals using BIM

In order for BIM to be successful in its implementation all industry actors have to be informed about the potential benefits to their profession (Gu et al. 2008). Together with that, all people involved with BIM needs to be skilled in its use in order to utilise these benefits (Arayici et al. 2009). Therefore the third group of barriers limiting BIM adoption is connected with the individuals actually working with the new technology and their needs of new roles and training to support the change. - 30 -

3.7.1 The new role of BIM model manager

Adoption of BIM will affect the roles and relationships of the participating actors as well as their work processes (Gu and London 2010). One new role in construction project is presented by Rizal et al (2011) in the form of a model manager.

Connected to the change in technology there is a need for a coordinating role in the form of a BIM model manager (Gu and London 2010). The Role of model manager will deal with the system as well as the other project participants. She will provide and maintain technological solutions required for BIM functionalities, manage information flow and improve the ICT skills of the other stakeholders. This expert role will demand knowledge in both ICT and the construction process. This actor will not take part in the decision-making regarding design or engineering solutions, or the organisational processes, but rather focus on the successful and collaborative use of BIM by all stakeholders. (Rizal 2011)

3.7.2 Training of individuals

When adopting BIM it is vital that the individuals are sufficiently trained in the use of the new technology in order for them to be able to contribute to the changing work environment (Gu et al.2008), (Yusuf et al. 2009). The importance of training was also one of the issues most often discussed in interviews by Aranda-Mena et al. (2008). For the implementation of BIM to be successful all affected members must be skilled in the use of BIM in regards to their specific field (Arayici et al. 2009).

Simultaneously a study by Yan and Damian (2008) revealed that most companies in their study who did not use BIM believed that the training would be too costly in regard to time and human resource. Further they argue that the issue of training is the largest barrier to BIM adoption because of the costs following the change. Decisions are mainly taken on the ground of business perspective, making a profit. Because of the insufficient number of case-studies showing the potential financial benefit of BIM the AEC-industry is generally not very interested in investing. There is also social and habitual resistance to change as many architects are familiar and satisfied with their current design tools and work processes and are sceptical to the benefits with this new technology. This results in that some actors are not interested in learning how to use BIM associated tools. (Yan and Damian 2008)

IV. EMPIRICS

4.1 Cases-study 1 – Campus Utbildningshus

4.1.1 Introduction to the project

In the year 2015 around 1100 new students will come to KTH campus at Valhallavägen and there will be a need for new facilities. Parts of KTH currently in Haninge (situated at the outskirts of Stockholm) will move into campus. The architectural school is also getting new premises, but lacking in house lecture halls, which they have today.

Consequently KTH is in need of new premises and there is a suitable space where a new building is being planned.

The results in this case study have been collected by interviews with the following actors:

- The Project manager for KTH

(ICITTESE-17)
ISBN: 978-93-86171-62-7

- The person responsible for developing the facility for use in the education
- One of the people who developed the BIM manual for Akademiska Hus
- Together with these interviews, information has been collected through protocol notes and Akademiska Hus BIM manual (Akademiska Hus (2013)).

4.1.2 Different actors and their roles

In Sweden the law prohibits universities to own their facilities, instead they must be rented. Currently the facilities at KTH campus at Valhallavägen are rented from Akademiska Hus, a state company owning the majority of university and college facilities in Sweden. Therefore KTH cannot construct the needed facilities by themselves but must rather negotiate with Akademiska Hus for the new construction. - 33 -

KTH

KTH is in need of new facilities for the education conducted at the university. The new facilities are mainly focused on the “department of Civil and Architectural Engineering” on KTH there are requests regarding the construction because of this education. Some early requests regarding the facility are the following:

- Enable conditions for innovative thinking, a flexible and creative educational environment
- Enable use of the facility and the technology in the education
- Show that KTH is innovative concerning sustainability and environmental issues

Together with this KTH is interested in constructing a facility that shows the university as a leading technical university preforming state of the art education.

Because of their role as tenant in this project KTH is able to put demands on Akademiska Hus regarding the project. Akademiska Hus on the other hand is able to demand higher rents from KTH if these demands and requests are associated with higher construction costs for the project. How these costs are allocated on all the facilities KTH rents from Akademiska Hus is also of interest for discussion. If the higher rents following expensive requests from KTH are limited only to the new planned facilities they will likely be less used because of the higher costs and thereby of less value to KTH as a tenant.

Akademiska Hus

Akademiska Hus is the project owner in this project. As well as KTH they view this project as somewhat of a prestige project to be able to show how they are able to produce buildings with high quality. Because KTH rents their facilities from Akademiska Hus, extra expenses to make the facilities correspond to requests from the tenant will result in higher rents. This enables an interesting situation when there are additional requests from KTH. - 4.1.3 BIM in the project

KTH

KTH has ambitious visions on how the new facilities can be used as an active part in the education. This new building serves as an opportunity to make practical examples that can be used in the teaching of students studying engineering at KTH.

The goal is to store this project as a practical example of how construction project are performed. Simultaneously there is an interest from KTH to equip the building with sensors to give data on how the actual building is performing.

There have been granted founds for parts of these requests. The project process will be filmed to provide actual information about how meeting and procedures in a real project are conducted. This material will later serve as material in research as well as possible educational material.

There are also a request that the building is constructed using the BIM technology. The major reason for this is that KTH is interested in using these models in the education. There are currently limited practical examples of the possibilities with BIM and to include practical experience with BIM models will be beneficial to the education. This material will also be available for research to further develop the technology.

To be able to benefit the most from these opportunities there have been request from KTH than the BIM models should be available for KTH by agreements in the contract. It is important that KTH have full access to the data in the model to be able to use it for its intended purposes. There is on the other hand no interest to make modifications in the actual model linked to the building because KTH will not do any modification to this facility themselves. KTH want access to extract data for analysis and educational purposes, but not to include more or modify the data in the model.

The request to use BIM in this project has not any direct connection to the performance in the project. There are no demands of lesser rents or any other compensation because of the demand for BIM, only the request to be able to access the models.

Akademiska Hus

Akademiska Hus is currently adopting BIM in most projects involving new construction. Projects concerning refurbishment or construction of extensions to current buildings are however mostly not produced with BIM. The decision regarding BIM adoption in a certain project is connected both with the characteristics of the particular project and the project manager. Project managers from Akademiska Hus with an interest for and experience with BIM are more likely to involve BIM in their projects. The type of project is also connected to the decision. Small project concerning refurbishment or reconstruction is generally not done with the support of BIM. In such projects existing documents and as-built drawings are generally not compatible with BIM and creation of BIM models for existing structures are quite expensive.

In projects involving construction of new facilities Akademiska Hus is ambitious in their goals with BIM. Akademiska Hus has developed a BIM manual instructing their project managers on how BIM should be used in their projects. According to this manual the goal with the use of BIM is to facilitate and improve communication and information exchange in the project. Thereby lowering costs by decreasing the amount of errors and improve the efficiency in the different stages of the project. BIM is seen by Akademiska Hus as the next CAD, which will be incorporated to take the next step in making the work processes more efficient.

Akademiska Hus emphasizes on the information part in BIM and makes a difference between BIM and 3d models. BIM is more than just design in 3D; BIM is the connection of objects and information to models and not just the model itself. Early participation by project owners, users, designers and contractors will facilitate the development of BIM models that correspond to the needs of all actors connected to the project.

Akademiska Hus also wants to use the models to support facilities management when the project is completed. This is defined in their BIM -manual meaning that the models can be adapted for use by facilities managers later. There are however problems with the use of BIM to support facilities management systems in the current situation. There is a lack of tools to take advantage of the information in the models and therefore these models are currently not well integrated in the on-going facilities management work.

4.1.4 The project so far

This project is in its earliest stages, not even starting the actual design of the facilities. From the perspective of the tenant, KTH is currently trying to specify their needs with the new building.

In this project there are uncommon circumstances due to the ambitious goals from KTH as to use the facilities actively in the education as well as securing environmentally friendly goals.

4.1.5 How barriers to BIM have been addressed

Connected with the adoption of BIM there are many barriers as described in the literature review. In this case study I have revealed how some of these barriers have been addressed in order to make BIM beneficial to the project as a whole.

Because this project is only in the initial stages these issues has just been planned for. This means that the proposed ways of handling the barriers are not jet implemented.

Interoperability

Issues regarding file formats and deliveries to and from Akademiska Hus are discussed in their BIM manual. Currently the demands on BIM for use to support the facilities management are under development. Due to the lack of developed facilities management systems supported by BIM, the BIM manual do not demand any specific file formats for delivery to Akademiska Hus. The designers should rather verify with the facilities management department at Akademiska Hus before specification for deliveries are made. Instead of specific demands there are suggestions of which file formats that should be used. It is suggested that the designers deliver both the native formats and in IFC. Together this means that a normal delivery will be in three formats:

- The file format agreed upon based on the facilities management guidelines
- Original file formats
- IFC

It is suggested that the IFC-files are used during the design phase to ensure that they are of high quality; there are however not any such demands in the current BIM manual.

Change in work processes

The actors most familiar with BIM tools are currently design consultants. These actors are quite used to developing 3D-models and exchange information to make their work processes more effective. What is not very common is the collection of these models to combine them into a single BIM database. Currently the problem in developing BIM models is mostly the client. The project owner is generally, either not interested in or not capable of handling BIM models.

Akademiska Hus has developed their BIM manual on how the models are supposed to be used in order to make the BIM adoption successful.

Education and training

This has not been deemed as a large issue by Akademiska Hus in this stage of their general BIM adoption. The project managers who work with BIM are the individuals with most interest and knowledge of how it should be used. The consultants and contractors generally have experience with BIM tools. The change in practice is mostly how models are collected and stored for later use.

4.2 Cases-study 2 – Nya Karolinska Solna

4.2.1 Introduction to the project

Nya Karolinska Solna (NKS) is a large and complex construction project which begun during the summer 2010 and will continue until autumn of 2017. These hospital buildings will include a gross area of around 320 000 square meters.

The hospital will be constructed and managed as a public private partnership (PPP) which will continue until 2040. This PPP is between Stockholm County Council and the project company Swedish Hospital Partners AB. The project company is the actor responsible for both construction and facilities management in NKS until the year 2040.

The results in this case study have been reached by interviews with the following actors:

- The person responsible for BIM usage at Coor service management
- A representative from Skanska working with the BIM deliveries

Together with these interviews, information has been collected through the NKS homepage (NKS-bygg (2012); Nya Karolinska Solna (2012)).

4.2.2 Different actors and their roles

Stockholm County council

The Stockholm County Council is the actor responsible for healthcare in the Stockholm region. Because of this, it is the actor ordering the construction of the new hospital buildings. The County Council Board facilities management (Landstingsstyrelsen förvaltning, LSF) is the actor responsible for the new hospital. Within this organization the subunit NKS construction takes on the role as client for the whole project, responsible for both the construction and the 30-year contract dealing with operations and maintenance of the facilities. - 39 -

The Karolinska University Hospital is responsible for developing the demands concerning the medical equipment as well as information and communication technology that the facilities are equipped with. Council Board facilities management is responsible for the procurement of the technical equipment and the other interiors needed.

Swedish Hospital Partners AB

The project company Swedish hospital partners AB finance and performs the actual project and is owned in equal parts by Skanska infrastructure development and the British investment fund Innisfree

Skanska

Skanska is the actor preforming the construction of the project through design/build delivery method

Coor service management

Coor is responsible for the facilities management of the facilities at NKS from its completion until the year 2040.

Banks

The project company is financed with investments from Swedish and international commercial banks. These actors also have the responsibility to ensure that the construction is proceeding according to plan and deliver their payments before the County Council will make their payments.

4.2.3 Public private partnership

The goal with the public private partnership (PPP) in this project is to enable a large degree of predictability and reliability for the society and the taxpayers. The solution establishes strong economical incitements for the project company to complete the project on time because the Stockholm County will not pay yearly payments until the project is completed.

The PPP model contains procurement of both the construction and facilities management of the hospital facilities. The project company is in turn responsible for constructing the facilities in accordance to the contract. The project company is also responsible for maintaining the fulfilment of the functions set by the client. If the project company fails in this commitment the yearly payment will be reduced. This gives the project company incentive to produce facilities that as sustainable over time.

PPP enables the County Council to predict what the cost for management of the hospital will be each year because the price is fixed and set in the agreement. This transfers financial risks from the County Council to the project company.

The County Council have made the assessment that the benefits that PPP enable is of large significance in a project with such large size and high level of complexity as NKS. The completion time is of especial importance because of planned restructuring in the highly specialised healthcare in the Stockholm County.

During operation of the hospital

When the project is completed and the NKS hospital is in operation the yearly payment to the project company will be 1 552 million SEK, calculated in 2010 years monetary value. - 41 -

During the whole project the County Council will supply the project company with a total of around 52 billion SEK which corresponds to around 27 billion in in 2010 years monetary value. These payments will supply for construction costs, funding, maintenance and operation of services connected to the building during the whole period from 2010 until 2040.

4.2.4 BIM in the NKS project

BIM was introduced to the project by the owner (Stockholm County Council) in the contract between them and the project company. In this contract there are definitions of what follows with the concept BIM in regards to the generated models.

In this project there are many models created to follow the project through its life-cycle. This life-cycle will continue until the contractual time ends in 2040 and at that time the model will be handed over to the County Council for future use. There are no demands of open formats in the contract between Stockholm County Council and the project company. Therefore issues of interoperability will transferred to the project company.

Furthermore the model will be object based, with attributes either directly in the model or linked to it. This enables spaces to be defined and connected to the equipment related to that space. In the contract there is no demand for open BIM formats like IFC to ensure interoperability.

The responsibility to combine the information from the designers is allocated to Skanska. The models from the different designers are all delivered in the program “Navisworks” which ensures that no file conversions have to be made by Skanska. The responsibility to document the as-built models is also allocated to Skanska as the main contractor. These models are later supplied to the facilities manager to support their continuous operation and management of the facilities. These models are also available for de design consultants in support of their work.

It has however not been practical to collect all information in a single model due to the large size of the project. The computing power is not sufficient to support the use of such a large model; therefore it has been broken down into many different models containing the information otherwise found in a single master model.

The role of BIM manager has also been adapted and such individuals have been present at the different actors to ensure good use of the models.

The process of how BIM was introduced

BIM was introduced to this project through the Stockholm County Council and incorporated in the contract between them and the project company. Within the Stockholm County Council there was one particularly interested person who was well informed of the possible benefits of BIM and therefore worked for putting

(ICITTESE-17)
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demands on BIM in the contact. The goal with the adoption of BIM in this project is however not very clear and a common understanding of what the models should be used for in detail is lacking. The ambitious BIM usage by Coor is somewhat a combination of the demand for BIM and interested and informed individuals in that organisation.

4.2.5 BIM in regard to the different actors

The tenant

The tenant (Stockholm County Council) has demanded the use of BIM in the project and later through the operation and maintenance of NKS. This has been done by inclusion of BIM in the contract between them and the project company.

The use of BIM will not have any direct consequences to the tenant because they are not responsible for the operation and maintenance of the facilities. On the other hand BIM theoretically enables greater reliability in the operation and maintenance of the facilities which will benefit the user, in this case the tenant.

Implementation of BIM also decreases the total risks in the operation and maintenance stage on the project, which could reduce the total costs for the tenant.

The contractor

The project is being conducted through the design/build delivery method. This transfers the responsibility for both design and construction to the main contractor, in this case Skanska. The contractual agreement to produce BIM models made Skanska responsible for the collections of the information needed in order to be able to combine it in to the demanded model.

Design phase

The project is of a substantial size and complexity due to the nature of the facilities. There are many different designers contributing information in order to complete the project. For these different designers, to be able to transfer information between themselves, agreements regarding which programs they are able to use have been made. These agreements ensure a suitable level of interoperability within the project. There have not, on the other hand, been any demands on the use of opens standards like IFC in this project.

The completed designs have then been converted and sent to Skanska in a pre-defined format to ensure the interoperability when the final models are combined. The work process in this stage has actually been the production of the different design disciplines models which are later combined by Skanska to make the BIM model, with all the information, defined in the contract.

This means that the adoption of BIM has not actually changed the work processes substantially in the design phase of the project, but rather worked as an additional tool to ensure good communication between the different design disciplines.

Construction phase

Skanska uses the BIM models in lesser extent in the construction phase, but not substantially. The uses are mainly to determine locations on the construction site. During this phase the model is continuously updated to be a correct representation of the building containing information of all building components as they have been constructed. This model will later be handed over to the facilities manager.

The facilities manager

The main usage for BIM in the NKS project is in the facilities management stage. Coor service management have very ambitious goal for their use of the models in their work processes. As with the usage of BIM in the earlier phases of the project, the initiation to the extensive use of BIM to support facilities management are found in the contract between Stockholm County Council and the project company. Coor as the facilities manager have developed their use of BIM and is aiming to have a far higher usage of the model than stated as a minimum in the contract. Currently the extensive use of BIM to support the facilities management in the NKS facilities has higher ambitions than in any other similar project in the world. This puts great demands on the success on the use of models in these processes both as a huge prestige project and as a possibility to demonstrate the usefulness with BIM in these stages of a buildings life-cycle.

BIM is information

To Coor as a facilities manager BIM is mainly a way of managing information. The traditional way of storing information in folders limits its usability. Contrary to such systems BIM enables databases to de linked directly to the model for easy access to the information. Systems supporting data management to ensure good management of information is of very high value to the facilities manager.

In the perspective of the facilities manager, BIM connects the enormous databases created by all the actors involved with the design and construction of the building to the facilities management system. This gives two benefits of specific importance in the NKS project:

Information management

Good documentation through a BIM as-built model will give the facilities manager the information needed to know what facilities there are in the building and how it should be maintained. Such knowledge is of great value both operating and maintenance staff, giving them correct information on what types of materials and functions the facilities contains and how it should be maintained according to the suppliers. Information regarding how the different spaces should be used and what activity they are designed for will enable more efficient usage of the facility.

To be able to document how the facility preforms will also be of high value to the facilities manager. The databases linked to the BIM model will enable storage of information connected to the performance of the facility and enable evaluation of which changes that could be made to improve its continuous function. According to Coor, BIM enables collection on hard data on how the facilities actually perform. Earlier this was done by softer evaluation by the professionals working with the facilities management. The ability to evaluate how different components preform will be directly connected to the costs of maintaining the facility.

If, for example, the elevators have an expected life-time of 15 years but are not working without problems, data on how much such problems might cost can indicate if this installation should be changed before the life-time ends. There are not only costs connected to maintenance related to installations not working properly. If the elevators are not functioning within defined parameters Coor will be subjected to pay penalties.

Collection and storage of the operating information will enable Coor to continuously make better estimates of how the facility will perform and what improvements that has to be made. This will both lower the maintenance costs and lower risks for penalties because of insufficiently functioning installations.

Traceability

BIM has the option of delivering traceability to an information management system. When the databases are linked to the model it is possible to identify both specific amounts and locations of different objects. This allows maintenance personal to know the specific location of malfunctioning installations and connect that to the product information stored in databases linked to the model.

(ICITTESE-17)
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There are also possibilities to deliver services connected to the specific activities within the facilities. In a hospital environment there is a need to be able to trace where certain equipment have been, like beds, cleaning equipment and so forth, to trace spread of infection. In this project BIM is aimed to be able to provide such information.

BIM allows new services to the tenant

In addition to enhancing and developing the functions of the facilities management system BIM has the opportunity to provide new functions to the tenant in the NKS project. There is a discussion how these processes can be developed but technically it is possible for Coor to provide many new services because of the BIM models with linked databases. For example booking of rooms can be done with support of the model, enabling administrative staff to find suitable rooms for patients directly through a search rather than making calls to the different departments. It is also possible to connect the cleaning of rooms with their usage rather than an ordinary schedule. For example rooms could be cleaned directly when they are being registered as empty by hospital personal and then registered as ready for use by the cleaning staff. There is also a possibility to connect the cleaning with the amount of use, for example automatically register a toilet as in need of cleaning when it has been used for a defined number of times.

These possibilities might sound futuristic but are totally realistic and achievable with the technology available today. The things needed for these new possibilities to be used are some changes in practice and new facilities management systems, but when implemented there will be a higher level of reliability for the user in regards to the quality of the facility as well as new improved services.

BIM transform the building into a function

The use of BIM will change the facilities management views on facilities. BIM enables emphasis of the functions that building provides rather than the building itself. In the NKS project this means a reliable management of the facilities that can provide new and improved services to the tenant. With a facility of such high level of complexity as NKS it is the function the different spaces provide that gives the value to the tenant rather than the spaces themselves. With a high level of BIM use to support the facilities management it will be possible to manage the facilities at lower cost and with higher level of reliability in addition to the new services possible.

4.2.6 How barriers have been addressed

Connected with the adoption of BIM there are many barriers as described in the literature review. In this case study I have revealed how some of these barriers have been addressed in order to make BIM beneficial to the project as a whole.

Interoperability

The issues of interoperability have not been addressed through open formats like IFC in the NKS project. It has rather been addressed on two different levels, namely between design consultants and deliveries to Skanska.

Between the design teams

The different design consultants are comfortable and most productive with quite different tools. As a way to ensure that these actors can remain efficient but still be able to interoperate, the design consultant had to agree on which tools they were going to use. To be able to use a certain tool there was a demand for sufficient interoperability with the other tools used by other actors.

(ICITTESE-17)
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This solution may have limited some actors with tools not able to interoperate with the other actors but the crucial issue of interoperability was sufficiently addressed.

Deliveries to Skanska

Skanska demanded that completed design elements should be delivered in a specific format to them. This enabled perfect interoperability from their perspective, and transferred issues with conversion errors to the - 48 - design consultants. This model was created in order to meet the demands in the contract as well as requests from Coor as the facilities manager.

Changes in work processes

According to representative from Skanska there have not been very large changes in the work processes due to the implementation of BIM. Many of the tools used today by designers are actually close to producing BIM models, but such models have not been exchanged and combined into a single collective model.

The difference in in regard to BIM use when comparing NKS and most other projects is the consistency by which design consultants models have been uploading their completed models into the master models managed by Skanska. Due to the contractual responsibility of Skanska to produce BIM models there has been a large incentive to ensure that these models have been correctly completed.

The largest changes to work processes the use of BIM enables to the life-cycle of the NKS project mainly comes later in the facilities management phase, where it will be used extensively by Coor. The collaborative work processed described in the literature has not been implemented extensively.

Education

The responsibility to educate their personal in how BIM should be used has been given to the different actors. However when most of them are familiar with the tools they use, this has not been a large issue in this project. The choice of solution regarding interoperability and traditional rather than collaborative work processes have enabled the different actors to remain in their traditional work processes to a high degree.

V. CONCLUSIONS

5.1 recap of the research question

The research question in this thesis is the following:

- How is the decision regarding BIM taken in a construction project?

Together with this main question follow these sub-questions:

- How the decision regarding BIM was made, what benefits and barriers was deemed most important?
- Which actors that were involved in this decision?
- How accurate the different actors understanding of BIM are?
- If there were a consensus regarding the decision or if single individuals drove the adoption process?
- How barriers to BIM adoption have been addressed in the project?

5.2 The BIM concept

The technology of BIM has benefits over traditional 2D technology. By improving the ability to manage information in construction projects, better collaborative work processes can be adopted. These processes can streamline the work in an AEC-project and thereby improving productivity. Improved productivity on a project scale is however not the only possible outcome of BIM adoption. BIM can be used at smaller scale by individual actors, with smaller potential benefits. The adoption of BIM must however correspond to the sought-after goal with the BIM adoption. BIM is not a goal by itself, the technology can enable changes in processes, making them more efficient, but BIM has no value in its own right. BIM has a value as a tool to reach other goals, but is not a goal by itself. Therefore the goal with BIM adoption must be developed before the processes for how the technology should be used are developed.

The slow adoption of BIM is linked with many different barriers, and there is no single one problem that could be solved individually to enable wide scale BIM adoption. BIM will enforce a paradigm shift in the industry with large consequences to how construction projects are performed. With adoption of this new ICT technology more efficient work processes need to be adopted. How these new processes affect the industry in regards to business models and practises is currently not fully developed. The individuals working with these new tools also need education to be able to use the BIM tools. BIM will change many individuals‟ roles in the project and there has to be a general understanding of the changes in practice. Together this means that technical issues are not alone the greatest barrier to BIM. When trying to break down the barriers to BIM adoption it is important to remember the process changes and needs of the individuals actually working with the new tools.

5.3 The implementation process

The case-studies in this thesis revelled that the driving force towards BIM often are interested individuals rather than a whole organisation striving towards economic goals. If the understanding of BIM and its possibilities is not well established in the organisation there is a risk of losing the goal of why BIM is adopted. Many potential benefits of BIM stem from enhancing collaboration, if there is no common understanding of what the models are going to be used for there can be problems in developing the correct models.

The lack of common agreement on a definition of BIM makes the concept vaguer. Depending on the type of actor the expectations on what BIM is differs. Because of the collaborative aspect of BIM this can be problematic as all actors must cooperate in the development and usage of these models.

The benefits with BIM have been established, but there are still costs connected with the adoption. The short term perspective in construction projects is an issue, as the project owner might not be able to profit from their investments in a single project. There is a need for more case-studies, both showing the profitability with BIM and revealing how the process issues have been addressed in these projects. At the same time there are competitive disadvantages for actors to reveal these results to the whole industry. - 60 -

For BIM to be adopted successfully, all actors in a project must participate in this change. Therefore there is a need for ability to make requirements regarding how BIM is supposed to be used. If a single actor is not contributing, much value in the models is lost because of the following inability to use them as intended.

6.4 To improve the implementation rate of BIM

It has been argued that the actor who should drive the development towards BIM is public clients. Project owners are generally the actor in the project in the best position to put pressure on other project participants to follow the new processes needed. Generally, public clients also have both a long term perspective in their projects as well as many consecutive projects. This enables them to benefit from experiences in earlier projects. It can also be argued that these public actors have a responsibility to make their experiences public, for the benefit of the whole industry, as higher productivity in the AEC-industry has socioeconomic benefits.

5.5 Further research

To better enable adoption of BIM in the AEC-industry there is a need to further research the following topics.

- Actual results of BIM adoption: As described in the thesis there is a need for more case-studies of completed construction projects investigating how BIM affected the result. Lack of data describing the effects of BIM is presented as an important barrier to adoption of BIM.
- The effect of BIM on work processes: Research on how adoption of BIM affects the work processes in a project and how these can be adapted to streamline practises in the project.
- How BIM results should be measured: There are currently no clear and good way of measuring the benefits of BIM. Inconsistency in how effects of BIM are measured makes results of case-studies less reliable and therefore makes such research less valid.

5.6 Afterword

As seen in other countries, UK and Norway for example, large public actors have power to set demands on the industry in regards to BIM. This is largely the case because of the large amount of facilities they own and are constructing. In Sweden the single public client Byggnadsstyrelsen was divided into many different public companies with the responsibilities for specific parts of the facilities previously owned by Byggnadsstyrelsen. Now, five of these public companies are collaborating to establish demands and standards regarding BIM adoption in their projects. These five companies are “Akademiska Hus” “Fortifikationsverket” “Riksdagsförvaltningen” “Specialfastigheter Sverige” and ”Statens Fastighetsverk”. This means that the development I call for is currently underway in the Swedish AEC-industry. How this will affect the adoption rate of BIM, however, will be revealed in the future.

After the completion of this thesis it has come to my attention that there is new research questioning the accuracy of the low or negative development of productivity in the AEC-industry. Depending on how productivity numbers are measured very different results emerge. This new research will however not affect the potential usefulness of BIM in regard to increasing the productivity. Even if the AEC-industry is not lagging behind other production industry in regards to productivity, its productivity numbers can still increase by improving upon the level of collaboration in a construction project.

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