UNIVERSITY OF GOTHENBURG

A Study on Risks and Benefits of Building Information Modeling (BIM) in a Construction Organization

Bachelor of Science Thesis in 'Software Engineering and Management'

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***Abstract*— During the past three decades, the construction industry has seen substantial improvement by using information technology. BIM is a fine example. The purpose of this research is to improve the understanding of BIM's benefits and risks in a construction organization, NCC AB. This study included different views about BIM from people in construction industry. People with extensive knowledge about BIM have been interviewed, from NCC, to get qualitative data for this research. In this research the qualitative data analysis had been used, empirical findings from this analysis helped to generate theories. The benefits and risks while using BIM in construction industry are being explored here. Several factors like communication and training which affect end-user and how NCC manages to make them adopt BIM are also have been discussed here.**

I. INTRODUCTION

The construction industry is one of the world's largest industries but it is also one of the most fractured (Hannes Lindblad, 2013). During the last three decades, the construction industry has seen a substantial improvement of the use of IT (Fisher et al. 2006). During this development, the most promising progress is building information modeling (BIM) (Eastman et al. 2011). BIM is described as a tool that enables the reuse of information and domain knowledge throughout the life cycle of the project (Vanlande and Nicolle 2008). BIM acts in a role to coordinate information exchange between different phases in the project (Hannes Lindblad, 2013). The potential benefit of BIM in construction projects is to improve the product quality to have more sustainable designs of buildings (Eastman et al. 2011).

BIM supports creating strategy and processes that can be used to support changes that might happen during the project life cycle (Eastman et.al 2011). Many researchers express that most failures in software systems could be the result of not addressing the relation between human and technical aspect of the software process (Acuna, Silvia, 2005). As Eastman expressed from this perspective, construction companies try to contain BIM as construction software to develop strategies that are compatible with any changes.

Getting a perspective of what could be the problems and benefits of a certain technology can help the academic community and industry. The industry can take decisions based on the research weather to adopt the technology in their organization or not. The academic community can be benefited from the data acquired in the research and getting to know the perspective of certain organization about that technology.

II. AIM AND RESEARCH QUESTION

The objective of this research is identified while framing the study. The objective is to explore the benefits and risks of BIM from an organization's perspective, NCC AB. In this research we also slightly explored some of the social aspects in the organization about the technology, BIM. As mentioned previously, this research could help both the academic community and industry. The study is done at a major organization, the results could be generalized to other companies, which might have similar organizational structure as NCC AB. But this should be done cautiously, more on this is discussed in external validity with an example.

A. Research questions

- *What are the risks and benefits of BIM from an well established, construction, organization's prospective?*
  - *What is BIM from the organizational prospective?*
  - *How are the risks being mitigated in the organization?*

Understanding what BIM is from the organizational prospective will make this research more relevant. Since as described below from literature, there are different views of BIM in different contexts.

Exploring the ways how the organization is handling risks would add value to the research. These results could be generalized in many contexts.

This research tries to answer this research question from NCC AB's organizational context.

B. About the organization

NCC AB is a leading construction and property development company in the Nordic Region. With annual sales of SEK 58 billion and approx. 18.500 employees (2013), NCC creates healthy environment for housing and business. NCC is active throughout the value chain to create environments for work, living and communication.

NCC develops and builds residential and commercial properties, industrial facilities and public buildings, roads, civil engineering structures and other types of infrastructure. NCC also offers input materials used in construction, such as aggregates and asphalt, and conducts paving and road services. NCC operates three businesses. An industrial under NCC Roads' aggregate and asphalt production. A construction and civil engineering business and a development business operated under NCC Housing and NCC Property Development.

III. THEORY - BUILDING INFORMATION MODELING

The use of information technology has been increased in the fields of AEC (Architecture, engineering , construction) to improve productivity and reduce costs, contrary to the projects which do not use or limit the use of IT (Fisher et al. 2006). One of the intelligent processes of this kind in use is BIM. It is predicted to be the predominant design and management tool used to design, review, approve, build, commission and operate buildings (Knight, D. 2008). 'Building Information Modeling' can be described as a set of processes and tools that enables storage and reuse of information and domain knowledge throughout the lifecycle of a project (Vanlande and Nicolle 2008).

BIM is a single data intensive online system with processes, enabling stakeholders to be included in all the phases of the project's life cycle (Hannes, L. 2013). BIM supports a re-evaluation of IT use in the creation and management of the facility's life cycle. Hannes (2013) expressed BIM as an IT and business enabler, BIM cuts across the traditional information silos supporting organization by improving integrated information requirements and current data abundance. NBIMS, (2007) defines BIM as a single data-intensive system, which acts as a central synchronized repository of

information for all the actors in every phase of the project. NBIMS abstracts that each and every individual part of the product (building, vehicle, etc.) can be seen as an object with relevant attributes like weight, material strength, load bearing capacity, etc. By using BIM, more stakeholders can be included in early phases of the project; where they can introduce their domain knowledge into the project which can make the system more data intensive (Smith, D.K and Tardif, M.). According to some experts like Smith, D.K. et al (2012) BIM is the process of collaboration between different stakeholders (professional teams) to create a centralized data model of a project and according to others like Taylor, J.E et al (2009) it is a synonym to parametric three-dimensional computer-aided design.

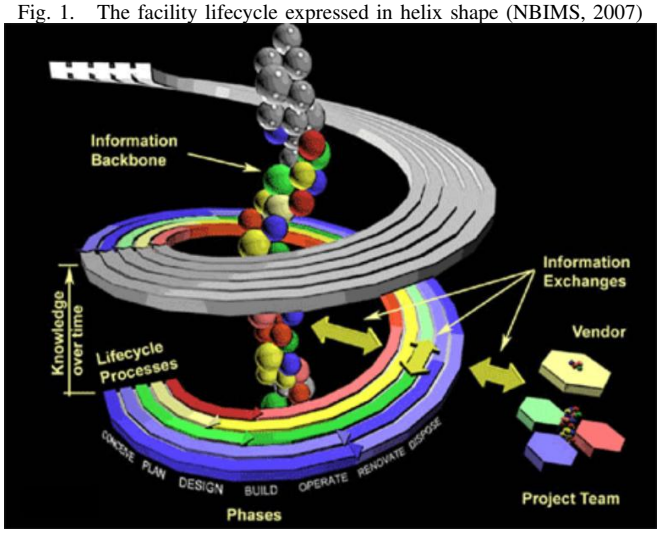
Currently, there is a lack of definition of what BIM is (Howard and Bjrk 2008), which makes the perception of the concept rather vague. According to Aranda-Mena, G., et al (2009), BIM is an ambiguous term that means different things to different professional sectors. Here we are describing and preceving BIM as defined by NBIMS (NBIMS, 2007).

To understand BIM, understanding the core concept underlying it can help the reader to acquire relevant knowledge. The facility lifecycle helix can be considered as a core concept of BIM. (NBIMS 2007)

A. The Facility Lifecycle Helix

Building processes can last for a long period of time, even after the development of a project (NBIMS 2007). During this lifecycle the project needs constant feedback, knowledge accumulation and information distribution capabilities. The figure 1. represents this in helix structure with the information backbone and the processes represented by different nodes surrounding it. The backbone is made up of integrated repositories which provide historical and current data, in turn which can provide alternative projections like cost-time-benefit analysis in early phases of project. Stakeholders are represented who exchanges information to make it more data intensive.

Fig. 1. The facility lifecycle expressed in helix shape (NBIMS, 2007)



BIM can be perceived in three different views, as a product, as a collaborative process and as a facility lifecycle management tool.

B. Different Scopes of BIM from literature perspective

BIM is the process of collaboration between different stakeholders (professional teams) to create a centralized data model of a project. (NBIMS 2007) As in product scope, the representation of the projects model in an intelligent manner will be done using the product, in process level with business standards, automated process capabilities and interoperability for sustainable information usage are defined in Collaborative process and in Facility lifecycle management scope, it is the repeatable procedures which teams can use throughout projects lifecycle. (Hannes L. 2013, NBIMS 2007)

1) Product: Here BIM is seen as a technical tool. As a product, using BIM tools, each object with attributes in the project is represented in 3D models which will evolve into more information intensive objects while the project evolves. These attributes are the building blocks of a central data model which can be accessed throughout the system at all the times by the stakeholders.

2) Collaborative process: Here BIM is seen as a process. As a collaborative process, BIM process covers business drivers, automated process capabilities and information sustainability.

3) Facility lifecycle management: Here BIM is seen as a framework. As a facility life-cycle management tool, it has information exchange processes, work-flows and procedures which can be used by stakeholders as a repeatable, verifiable, transparent and sustainable information based environment used throughout the projects life-cycle.

According to Aranda-Mena, G., et al (2009), BIM is an ambiguous term that means different things to different professional sectors. It is defined in various ways according to different professionals, thus it can be viewed as following:

- BIM as a software tool.
- BIM as a process for designing and documenting building information.
- BIM as a whole new approach to practice and advancing the profession which requires the implementation of new policies, contracts, and relationships among project stakeholders.

C. Potential Benefits of BIM from literature perspective

Because of centralized data model, with emphasis on information exchange between stakeholders and objects, it helps to increase productivity, which in turn decreases project costs while increasing communication. (Salman A. 2011) Due to visualization of model before proceeding to physical project development, it is easy to avoid physical conflicts and rework of the same task. The BIM processes helps to manage change in orders, makes ease of maintenance, increases quality of the project (David B. 2012).. It helps to improve building performance, to develop a sustainable design and construction, reduces time and cost for design and development of the product. Due to interoperability

and information exchange made easy by BIM, it helps to reduce or in some cases total elimination of RFIs (Request for Information) from and between stakeholders (Kristen B. et. el. 2012).. Following the above information, benefits are described below, categorized into sections (Eastman, C.et. el. 2011):

1) Pre-construction Benefits to Owner:

- Concept, feasibility and design benefits
- Increased building performance and quality
- Improved collaboration using integrated project delivery

2) Design Benefits:

- Earlier and more accurate visualization of a design
- Automatic low-level corrections when changes are made to design
- Generation of accurate and consistent 2D drawings at any stage of the design
- Earlier collaboration of multiple design disciplines
- Easy verification of consistency to the design intent
- Extraction of Cost Estimates during the design stage
- Improvement of Energy efficiency and sustainability

3) Construction and Fabrication Benefits:

- Use of design model as basis for fabricated components
- Quick reaction of design changes
- Discovery of design errors and omissions before construction
- Synchronization of design and construction planning
- Better implementation of lean construction techniques
- Synchronization of procurement with design and construction

4) Post construction benefits:

- Improved commissioning and handover of facility information
- Better management and operation of facilities
- Integration with facility operation and management systems

D. Difficulties related to BIM from literature perspective

As of any there are down sides to BIM, most notable are described here briefly:

1) Product related:

- Interoperability
- Different views on BIM
- Poor match with the users needs

2) Process related:

- Changing work processes
- Risks and challenges with the use of a single model
- Legal issues
- Transactional business process evolution
- Lack of demand and disinterest

3) Individual / people related:

- The new role of model manager
- Training of the individuals

IV. Methodology

A. Framing the study

While framing the study we narrowed down the research area. The result from the literature research was useful for focusing the study on BIM and it helped the researchers to decide on the orientation of research. Therefore this study ascertained that people with a wide knowledge of BIM should be interviewed in order to understand the organization's perspective of BIM.

As suggesting earlier, literature research conducted has also helped us to acquire ideas on how the research should be done. The ideas include *'What process should be used for data collection?'*, *'How the data analysis can be done?'*, *'How to support the empirical findings?'* and such. Search strings are used to gather relevant research material. The search strings are derived from the research question, finding synonyms, alternative spellings and antonyms to the words. The strings are also from related research papers, the keywords and synonyms mentioned in those papers.

In the research these search strings are used:

- BIM
- Building Information Modeling
- Benefits
- Risks
- Implementation
- Construction

Some of the search queries derived from these strings are:

- BIM Implementation, Multidisciplinary Construction Context
- BIM benefits risks
- BIM implementation process in construction projects

More of these can be found in Appendix.

The search strings are used in these digital libraries and web search engines:

- Engineering Village
- INSPEC
- IEEExplore
- ACM Digital library
- Google Scholars

B. Research Design

Here, we are going to explain how this research is designed to answer the research question and motivations behind why these methods are chosen, with relevant support from literature. The research design provides a plan for data collection and data analysis.

The main focus of this study is to get an in-depth understanding of practical challenges, benefits, risks and such of BIM from a well established organization's perspective. In this research, some of the social aspects in the organization are also studied and included. S. Easterbrook et al. states that positivist approaches have little to say about the richness of social interactions. On the other hand, constructivism offers methods that collect rich qualitative data about human activities, from which local theories might emerge. According to Carson, D. et. el (2001) using exploratory study qualitative

data can be obtained, which can be used to support or negate the research question one is working towards. An exploratory study needs to be done where qualitative data from the organization can be obtained and analyzed.

Robinson calls case study a research strategy and stresses the use of multiple sources of evidence and others like Benbasat makes it clear, mentioning information gathering from few entities and the lack of experimental control. It offers an approach which does not need a strict boundary between the studied object and its environment (Conradi R. et. el, 2003), the artifacts obtained by case study can be generalized for other organizations who might be developing these systems. Selecting a case is a crucial step in this research.

This research methodology can be described that it inclines towards a case study research. But due to different school of thoughts on 'what a case study means' exists we are mentioning it as a study which has a case company and elements to study i.e benefits and risks.

The process of collecting qualitative data in this research was done while framing the study. Parallel to this, literature research was carried out in order to get a deeper understanding of the field and to support the results obtained from the data. The literature research was done in an iterative way to improve our understanding about BIM throughout the research.

a) Data Collection using Semi-structured interviews: Interviews are conducted with a variety of objectives. Seaman (1999) indicates that they are used to collect qualitative data of opinions or impressions about something. Interviews can be used in combination with observations. According to Runeson et al. (2008) the interview questions should be based on the topic of interest in any study. The interview questions are mostly based on the formulated research questions. We also structured the interviews using the questions which are elicited while framing the study. We also left parts of questions open-ended to maximize the quantitative information from the subjects. Thus making our data collection method a semi structured interview (Seaman, 1999). According to Seaman (1999) if the interviewees are kept blind about the goals and objectives of the study they might not have enough incentives, assuming the research is not valuable, to participate in the study. And if too much information is revealed interviewees might filter the information or leave out the information thinking interviewer might not need it. So information about the topic to be shared with the subjects had been carefully controlled.

To handle the subjects who might be wondering off from the topic, we gently tried to steer them back to the topic and on the other hand the subjects who shares the barest minimum are handled by limiting questions which can be answered with an 'yes' or a 'no'. If in case those questions are to be asked, follow up questions about the details of the topic are asked to gather more quantitative data. Often people mistakenly believes that anyone coming to interview or observe them is really there to evaluate them (Seaman, 1999). To handle this, we assert on making them know that there are no correct answers and dispel any perception of interviewer as an expert in the area.

An interview guide is prepared to help interviewer to organize the interview with consists a list of open-ended questions, with notes about in which direction to steer the interview in different circumstances. In general, it is difficult for an interviewer to take notes and conduct the interview at the same time. So an audio tape has been recorded during the interviews. When the interview has been recorded it needs to be transcribed into text before it is analyzed (Runeson et al., 2008). The recording is then transcribed and used to take notes after the interview to extract data to analyse.

The reason for using semi-structured interviews was that, it will open up a possibility to have conversation around the subject of the research. Also other advantages by interviewing employee are to have a variety of opinions from different entities that play an important role in the field in which this study is focused. Another positive action to have this interview is highlighting the interview frames to understand the research issues.

There are some limitations using this method of data collection. This data collection depends upon the interviewees' availability. Firstly researchers are required to find people that can contribute and are relevant to this research. It is required to motivate interviewees in order take part in the research. Furthermore, the interviewing is a long process, as it takes time to arrange meetings with interviewees and researchers usually wait for a long periods of time without any response from the interviewees.

b) Description of the interviews and interviewees: We have used *'Purposive/Judgmental sampling'* (Nonprobability sampling) to select the subjects, who are more relevant to our research, rather than random sampling. The subjects are a composition with variety of roles in the organization. To get in contact with the subjects we used a gatekeeper in the organization, who is also one of the thesis authors. The subjects are selected by this gatekeeper, the primary contact. This might introduce bias in selection, but it has been limited by using all the available contacts in the organization, (Purposive sampling). All interviews in this research are from *'Nordic Construction Company'* shortly referred as NCC AB. All interviewees are relevant people with experience of using BIM in different construction projects. The reason behind calling them *'BIM experts'* is their experience with BIM. All interviews were conducted in English and they were recorded and transcribed in English as well.

We have to deal with the fact that the study has been done in one company which might lead the subjects to be biased about their statements in the interview. To minimize this we ensured total anonymity to the subjects regarding the data.

Before every interview, the author of this thesis selected people who work in the department of VDC (Visual design construction) at NCC. They were contacted through email to organize meetings and interviews. The researcher asked relevant questions within the research area during the interviews. The researcher also asked them if they could suggest anyone who would be beneficial and interested to include

in this study. This helped to increase the sample size of this research. The duration of each interview was about 45 minutes.

TABLE I
DESCRIPTION OF THE INTERVIEWS AND INTERVIEWEES

Interviews	*No.of interviewees*	*Interview Time*	*Experience*
BIM Expert	*2*	*45 Min*	*7-8 Years*
SPM	*3*	*45 Min*	*6 - 7 Years*
Trainee	*1*	*30 Min*	*5 Months*

1) Data analysis: In this research, qualitative data was collected and analyzed with qualitative techniques. As Bryman (2008) stated qualitative data analysis is a useful method because of the impressiveness of the information findings. In this study, literature research and semi-structured interviews are conducted to get the data. This section covers two areas- the way the data is analyzed and the way the data was compiled together is elucidated here. According to S. Easterbrook in any research the theory becomes a lens through which the work is observed. The real work phenomena are too rich and complex to study without huge amount of filtering. In qualitative methods, the lens is often applied after data is collected, to focus the process of labeling and categorizing the data.

Qualitative analysis has been performed on the data collected. We transcribed the interviews into text. After the interviews were transcribed, a number of codes (Keywords) were identified. These categories can be mentioned as the core aspects that should be described in an attempt to answer the research question. Here the researchers have coded the text from the data with different codes representing different areas. Each code have sub-codes. This is then combined with the comments and reflections by the researcher. The data is then tabulated with the coded data. As Robson suggested, the analysis could be conducted at different levels of formalism. We used Editing approaches, which included few priori codes that are defined based on the findings of the researcher during the analysis Runeson et al (2008). The preliminary set of codes was: implementation, experience with BIM, and knowledge of BIM and current projects. Identifying and classification of codes were done by two researchers individually. The researchers drew conclusions after finding keywords in the material and grouping them together. In order to avoid bias, the analysis had been conducted by multiple researchers. They were compared by discussing the similarities and differences. The preliminary results from each researcher is then merged into a single result. This methodology allowed the researchers to compare several opinions from different interviewees and it was the initial point wherein possible findings were generated. The process is shown in figure 2.

In this research, the following method is being followed:

As seen from the figure 3, the initial step is to research the topics i.e BIM. Then the interview questions were derived, later the data had been gathered through the interviews. The data then been analyzed as mentioned above with the keywords or codes identified from the qualitative data. Then these are classified into categories, concepts are established and compared these from the both researchers and defined them into findings. This process continued in an iterative fashion while checking the findings.

Fig. 2. Process for analyzing data from interviews (Bryman A, 2008)

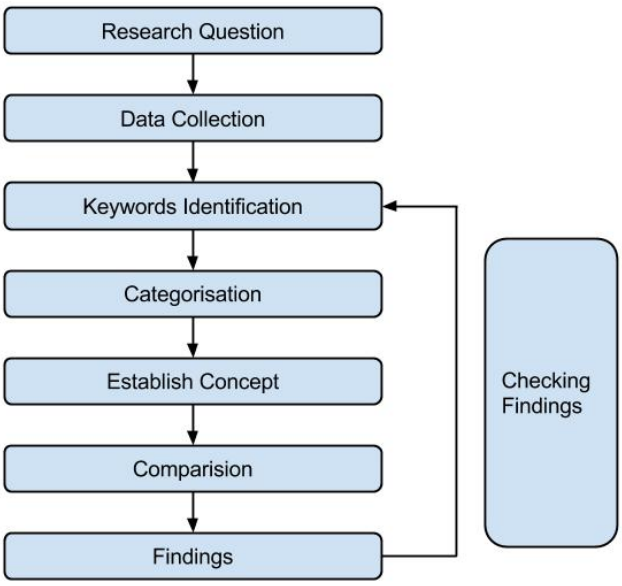
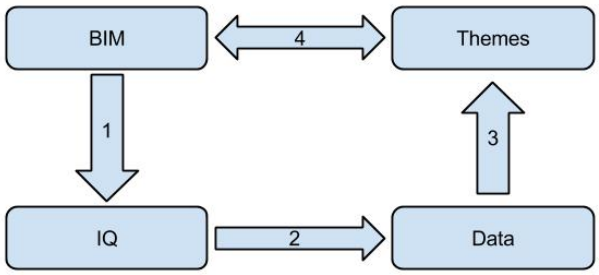


Fig. 3. Steps followed in the research



C. Validation of the study

According to Seaman (2009), there are number of methods and approaches to strengthen a proposition after it has been generated from the data. After careful evaluation of the methods by the researchers, different techniques are used to ensure the validity of this study as suggested by Shull et al (2008). The paper discussed validity in two parts, Internal Validity and External Validity.

1) Internal Validity: To ensure the internal validity, since this study doesn't have different data sources, triangulation couldn't be employed here, but the researchers went back to the participants to ensure that interpretation of the data is valid from their perspective. This method was mentioned by Shull (2009) as 'Member Checking'. The researchers did the data analysis individually initially and then compared the results. The researchers also did a peer debriefing; before reporting findings, researchers explained the findings to each

other, who asked questions about the study and the theories discovered. This helped the researchers to reflect on the findings from different prospective and also helped to make the final reporting of the findings as valid as possible. In order to increase the validity of this study only interviewees with relevant knowledge in BIM are selected.

2) External Validity: The external validity of this research is important to apply the research in different contexts. Since this research methodology is leaning more towards an case study, the generalization of it could be biased. But there is no bias in understanding the organization's situation. Still this study could be generalized in some aspects, the aspects which doesn't depend on the organization. The general aspects like, 'training the employees on BIM, will increase productivity' is an important aspect and can be generalize but aspect like 'BIM experts from VDC council should push people to adopt BIM in their organization to increase productivity' is a more specific aspect to NCC, which wouldn't make any sense looking to generalize this. The reader must behave cautiously and must be aware of the situation before doing that. The researchers tried to the best of their capabilities to include concepts and the situations in which these results are generated are explained in this paper.

V. Results

Here it is given more importance to certain aspects of risks related to BIM. It is done so, because of the data, strongly pointing towards the importance of training the individuals in the organization about BIM and it is also identified as a major risk the organization is trying to resolve. Although the research question is being answered here, there is an emphasization on this particular risk and how it can be resolved. So an extra section is added about managing BIM knowledge.

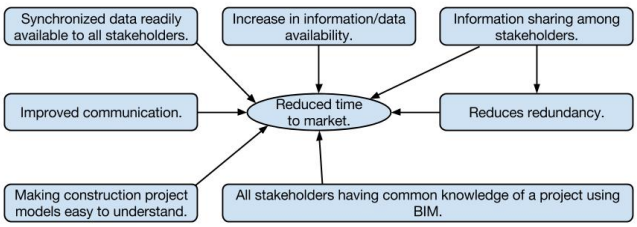
A. Benefits related to BIM

As mentioned by one of the interviewees *"The benefits [of BIM] are less waste, better high quality and control and faster process. So, its time, money and quality. Its only three magic goals that every company is trying [to acheieve] "*. In general all the interviewees agree that using BIM to develop projects have considerable benefits compared to projects developed using traditional methods and processes. Many of them directly or indirectly help the organization to save time, improve quality and reduce cost. We tried to answer the benefits using these three categories.

1) Time:

- From the BEs *"in traditional way we redo a lot of work"*. Handling redundancy is another major issue for the organization, in order to save time and in turn decrease the cost.
- Sharing the information among different departments is crucial for the project to be executed successfully. If not, there could be problems like clashes in the site, redundancy and others alike. While using BIM, the information recorded by a professional is readily available in central repository. Thus sharing this information will be less hassle compared to traditional processes where only CAD or 2D designs are employed. And from one of the interviewees *"With BIM you can have very effective workflow and work process. And if you compare it with traditional way of design process."* which supports that BIM is crucial to achieve effective workflows and processes for the organization, compared to traditional ways.

Fig. 4. Time



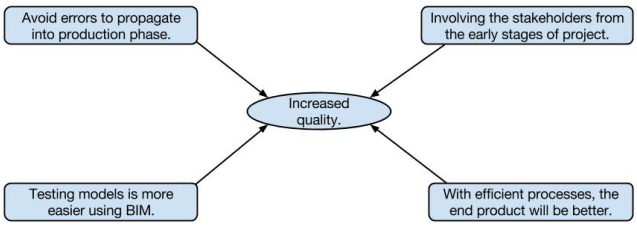
- Sharing the information and making it available will helps to avoid the redundancy in the projects.
- Synchronized data will help the stakeholders to save time, since they need not have to wait for the information to arrive in other forms i.e on paper as 2D drawings, reports of an order and such.
- There is an inherent need for the organization to understand the needs of clients. Sharing information has been proven to be an important aspect for this. The information also helps the people involved to understand the situation of a project, more easily. Thus, this helps in gaining a clearer picture of a project among all the stakeholders. Using BIM can drastically improve this situation, as one of the BIM experts mentioned in an interview *"We need to have this model, need to work together with our clients like small company in the project, we need to share everything"*. This signifies that the information needed to be shared with the clients and contractors to make them gain a common knowledge about the project. This common understanding will save time in the projects.
- The benefit of using 3D model in BIM is, it can represent the visualization and complement the drawings. The exact statements by one of the interviewee, who is working as a Trainee at NCC stated that *"BIM is a powerful way to visualize the building in different contexts."*, *"I have also used the 3D models as a tool in various coordination meetings where we are several players who need to understand a situation; even the working aspect becomes clearer to take into account when the 3D model is used as a basis for a common picture."* This saves lot of time for company while making the models easy to understand.

2) Quality:

- Avoiding the errors to propagate to the production phase of the project is an important aspect to increase the quality of the product.

- As mentioned earlier using BIM the information is readily available, this makes testing of models easier and avoids errors from early stages of the project.

Fig. 5. Quality

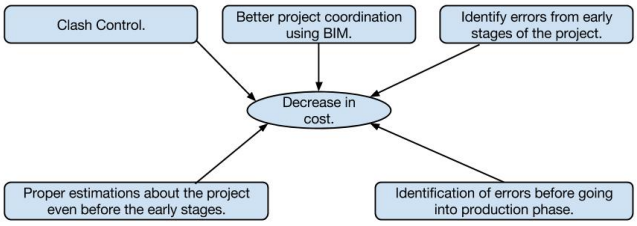


- As mentioned by a BIM expert *"In generic sense, you get better end product and in a more efficient way, you can optimize it. Mostly you can use other people's experience and knowledge in a better way, to collaborate, to make decisions about the end product. Then the process will get more efficient and end product will get better, in a way"*. This supports that BIM helps to increase the quality of the product.
- The interviewees suggested that, With better use of BIM, BEs can pursue the customers to participate in the project from the early stages of development. This drastically increases the quality of the product.

3) Cost:

- BIM helps to avoid the clashes in the project. The clash control helps the project coordinators to better manage them arising in the project.
- Using BIM helps the organization to realize the models realistically, with all the related information. This can be used to make proper estimations about cost, time and such, while visualizing the building in different contexts. This also makes it easier for several stakeholders from the early stages, where they can contribute information from a professional perspective. This makes the project more data intensive.

Fig. 6. Cost



- Having a data intensive system will decrease the cost of the project.
- BIM helps to identify errors even from the early stages of the project.
- Identification of errors before going into production will help to decrease the costs of the project.
- These factors mentioned above indicates that the projects using BIM have a comparably higher return on investment to projects using traditional ways.

The above mentioned items correlates with the benefits observed from the literature. There are certain benefits which are not being mentioned by the interviewees, mostly about 'Post construction benefits', although one of the interviews mentioned that NCC is not handling the maintenance of the products after construction this data is not sufficient to derive any theories. So no comments can be made on it.

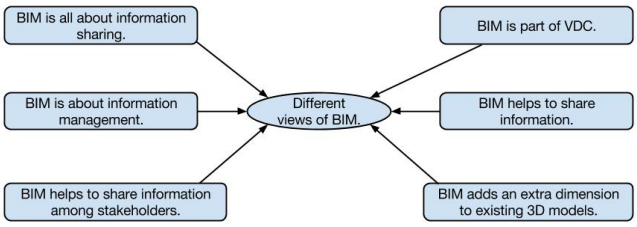
B. Difficulties using BIM

The identified difficulties related to BIM are :

- Different views of BIM
- Interoperability issues
- Lack of demand and disinterest
- Knowledge of BIM among the stakeholders (or) Training of the stakeholders.
- Legal issues

1) Different views of BIM: As already mentioned, there are different views of what BIM is among different different professionals. At NCC, BIM experts and senior project managers agree that there are different definitions of BIM but individually they share a common idea that BIM is all about handling or managing information. And also that it is about making the information available for the people involved. They agrees that it is not just a software program. It helps to visualize the building in different contexts. In some cases BIM is viewed as 3D models with all the necessary information provided, which is needed by all the involved personals in the organization. According to BEs, BIM is all about *"To get together and share the information"*, *"Everyone gets the same picture of the project"*. This supports the claim that everyone agrees that BIM is about information sharing and management. The other sources indicate that BIM is part of VDC (Visual, Design and Construction), where it is used as an information system, which can help to support the processes defined in VDC.

Fig. 7. Different views of BIM

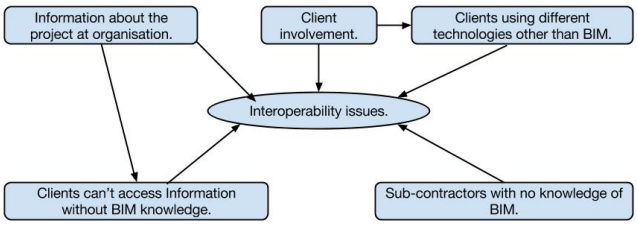


An employee agrees that it is all about information management. Some others tend to refer it as a VDC process; some as a part of VDC and others refer it to as a system, which adds extra dimension to the existing 3D model systems. About BIM as said by BIM expert (BE) and senior project management (SPM) *"we should only do it once and then like send it to a database, then everyone can get that information"*, indicating that when BIM is being used, the information about the project will be updated to a database. And all the involved personnel can access this information. This again supports that, the BEs have same ideologies

about BIM within the organization. This view is also been discussed in the discussion section.

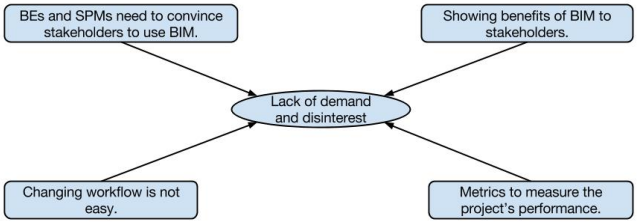
2) Interoperability issues: The client involvement is an important factor in construction projects, as mentioned earlier. Also when the organizations use sub-contractors, it is important for them to work with the same methods and processes as the organization. It is important, for example: the information needed by the subcontractors will often be with the organization, if they use anything other than BIM, there could be interoperability issues arising between them.

Fig. 8. Interoperability issues



3) Lack of demand and disinterest: To the BEs, the difficulty is to make the management understand the benefits of using BIM. That is crucial, because they are the one who takes the decisions regarding any changes in the processes. Changing this workflow is not an easy task, as the concerns expressed by the BEs, that 'changing workflow or process in one department will create ripple effects in the whole organization', by time this might lead the organization into adopting change successfully or might completely lead to failure of the organization.

Fig. 9. Lack of demand and disinterest

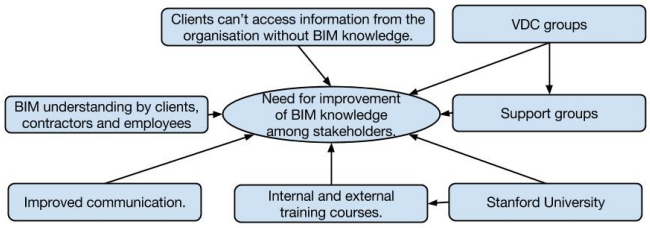


Encouraging them to move from traditional work processes to BIM is another difficulty to the BEs. This indicates that there exists a problem of having disinterest about BIM in the organization. Realizing that the personal having no knowledge about BIM is costing the organization more compared to personal with BIM is encouraging the organization's management to adopt BIM. It is important for BEs to convince the management that there are foreseeable benefits by using BIM.

To help improve this the metrics to show the benefits of BIM could be used. But the metrics to measure the project's efficiency, time, costs and others used during the traditional ways of working wouldn't be much relevant while using BIM. As said by one of SPM *"I would say we need to get metrics to tell everyone that the company earns money because we work with BIM"*. Metrics like *"Number of projects using BIM"*, *"Number of projects not using BIM"*, *"Profit and loss of these projects in terms of money"*, *"Time took to deliver these projects"* and so. So a research on how this situation can be improved would help the organization to resolve the disinterest issue.

4) Knowledge of BIM among the stakeholders (or) Training of the stakeholders: As mentioned earlier, the information needed by the subcontractors will often be with the organization. In order for them to access the data from the organization, they need to be familiar about BIM and how to use it as a tool.

Fig. 10. Need for improvement of BIM knowledge among stakeholders



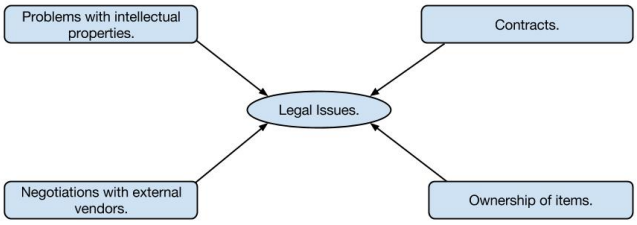
BIM experts assert that the contractors and clients need to understand what BIM is and start working with BIM in order to make the project successful, it can be observed from many statements like *"we need our clients to work with the BIM"*. If not they might not understand what the organization's needs are. *"So we have the information they need but they don't know how to take care of it"*. As mentioned previously, the personal having no knowledge about BIM is costing the organization more compared to personal with BIM suggests that equipping the personal with BIM knowledge is quite an important aspect from the organizational prospective. As mentioned earlier 'Knowledge of BIM among the stakeholders' is quite an important aspect to discuss. Since it and how the training of stakeholders are done are discussed in separate section 'Managing BIM knowledge'.

5) Legal issues: According to a SPM, one of the major issues while negotiating contract with external vendors is with intellectual property. BIM can be used to share the intellectual property as specified by the product owner but BIM process it self doesn't have any clear indications on how to resolve the issues related to intellectual properties like floor plans, ventilation systems design and others a like. The ownership of these items will entirely depends on the organization and clients' agreements. In NCC, the BEs in the organization are putting the demands and guidelines in the contracts, which are called VDC demands, that have to be followed by the other parties. This is helping the organization to manage the intellectual property issues.

C. Managing BIM knowledge

Improving BIM knowledge among the stakeholders is quite important for the organization. The organization is supporting the stakeholders with right tools, to help them understand BIM and start working with it. Some SPMs stated that there are BIM groups at the organization to support users

Fig. 11. Legal issues



to get a general understanding of 'What BIM is?', 'What it does?' and 'Why they should use BIM?' This group's responsibility is to hold meetings and workshops for employees in order to make better understand of BIM to users. This can be supported from one of the interviews saying *"This group is in charge of development and implementing VDC or BIM in the different department and we do that, we the network and the contact persons and we also do educations and information of course and support."*. The BEs and SPMs provide both the internal and external training for the stakeholders on BIM. One of the BEs stated that *"We go to seminars, we go to external educations. For instance we have company design education, which is VDC certification program that is where exactly Stanford university [comes into the picture]."* The organization has also been collaborating with Stanford University, to support its employees with different courses and training programs, which include BIM. All these activities are done to improve the knowledge and convince the stakeholders to use BIM. This can be supported from one of the dialogue from a BE saying *"We produce our own training and courses and material for that to some extent. Or buy [services from] someone else."* Addition to that, to convince the employees including SPMs to use and promote BIM, BEs shows them the successful projects as success stories. Communication is a primary aspect to BEs to maintain a balanced knowledge about BIM to the people involved in the project. As stated earlier, it is important for them to know how to work with BIM and peruse them to use it by making them understand the benefits with it. As said by an interviewee *"Subcontractors, customers, we, have to have balanced level of the [BIM] knowledge, so that we understand each other. Why we do that?, Why we implement BIM?. What is the benefit of BIM in the process?"*. The information retrieval, integration, consistency, and exchange will be made easier when the involved personnel know how to use BIM. The reason behind the emphasis on communication is, when employees are in a group in order to achieve goals of a project in the organization, it is expected to share and exchange the information. Thus, even from the design phase of a construction project, people working with BIM have to share their design in order for the information to be interpreted and used by other users from the beginning to end of the project. As BE mentioned *"they need to apply the strategy of [sharing information from] the early stage[s] of a project "*.

D. Comparison of results with related study

The most relevant research to this study is by Azhar S. (2011). Therefore our research findings are compared with Azhar S. (2011)'s research findings and found some common and varying theories. The cost of adoption of BIM is not a problem according to Azhar (2011). As a part of our research an aspect is to see if the cost to implement BIM might have any effect on adopting BIM in the organisation. The return on investment is higher, this has been observed in both the theories of the research papers. But the exact range of BIM's return of investment (ROI) is hard to conclude because of the large spread of the data (Azhar S. 2011). Our research doesn't have any quantitative data to conclude this theory. Time to delivery is another theory discussed by Salman A. (2011), our findings suggests that the project's time to market is improved while using BIM. This theory is generated in this study by analyzing qualitative data, and also in Salman A. (2011) study it is proved with quantitative data analysis. There are risks identified, which are discussed in both the research papers. There are issues on BIM data ownership; this has been handled using contracts. The risk identified and possible solution to the risk has been the same in our research findings and by Salman A. (2011). There is another risk identified by Salman A. (2011) on, 'Who should take responsible for a misshapen in the project?' It hasn't been investigated in our research. Interoperability issues are raised and discussed in our research and identified as a problem also by Salman A. (2011). If the contractors and subcontractors are using the same software it wouldn't be much of a problem, when they are not it is identified as a risk. As it raises compatibility issues among the technologies used.

VI. DISCUSSIONS

In the benefits of BIM, we tried to address them by categorizing into three. Those are time, cost and quality. It is important to understand that they are related to each other and one of these aspects directly or indirectly affects another. For example in technical sense, using a technology if the time to market of a product is decreased the remaining time could be used to increase the quality of the product or release the product to reach the customers before the competitors. This could increase sales, so the profits and in a sense it can be said the cost is decreased. If in case using the technology the cost of the product is decreased, the organization could expand their operations to increase quality of the product and/or to reach the market early. In the same way these are inter-related in construction industry too. One can interpret reduce of cost as increase in quality and another as decrease the time to market. The interpretations depend on the individual's perspective. It is being described in categories because it can help the reader to understand benefits easily.

Although in the organization, BEs and SPMs might be preconceiving BIM as system to manage information, observations from data suggests that there are some inconsistencies among BEs and SPM. This doesn't mean that the

results mentioned that they share a common idea of BIM regarding information sharing and management is invalid. Here we are merely suggesting that there are inconsistencies about where BIM fits in the organizational culture. One sees it as a combination of processes, tools and guidelines and the same person sometimes refers BIM as a pure technology. Some suggests that it is just a tool to exchange information, as said by one of the interviewees *"For me, BIM is just a carrier of information. It's a way to handle information for different purposes. So its really like a bucket of information that I am supposed to [..] use for different purposes.'* and the same person later in the interview mentions that *"BIM is just a part of VDC, so we say that BIM is the actual building information model, the carrier [of] information and the VDC is the coordinated process, process [that]is [used] to work with the information"*. It also contradicts the idea of using more matured systems in construction industry for information management. As said in an interview *"I have about 15 years [experience] with machine and automotive industry, [..] they work in very similar way. We call it BIM for the information models. I would say the automotive industry is much much further in working with PDM and PLS systems [for information management]. And that sort of amazes me why the building industry doesn't work with those systems'*. The idea that more matured information management systems are not replacing BIM should be realized as that BIM is not just about information. It is much more than that, if not it would have been replaced in the company by any of the tools that have been adopted from automotive industry.

Regarding the BIM knowledge BE's approach to make continuous improvement of employees and organization is through communication. It is mentioned in the interviews as an important factor. And it is also important to make sure everyone in the organization has sufficient level of BIM knowledge. According to the interviewees, improving the BIM knowledge among the people involved in the projects at the organization is a challenge, which they need to deal with. One way of increasing the process of value generation for user could be through training courses at the company and collaboration with academia. Based on the interviewees another way of achieving this is by improving collaboration between stakeholders, who can help each other. The construction organization should consider users as a core factor in BIM process. This will improve the opportunity for the organizations to improve collaboration between stakeholders through sharing more information. It's necessary to encourage employees to move from traditional work processes to BIM and it is important for BEs to convince the management that there are benefits by using BIM.

VII. CONCLUSIONS

This research outlined risks and benefits of BIM from an organization's perspective. The major benefits are 'increase in quality', 'decrease in cost' and 'decrease the time to market' while using BIM. The major difficulties are 'different views of BIM', 'interoperability issues', 'lack of demand and disinterest', 'knowledge of BIM (or) training of the stakeholders', but the organization has been giving more importance to increase the BIM knowledge among stake holders. In the organization BEs and SPMs share a common idea about BIM that, it is a information system, with processes specifying how to use the system. The BEs and SPMs are trying to mitigate risks using their expertise. For example, legal issues regarding intellectual properties are managed through contracts with clients, lack of BIM knowledge is being handled by BEs and SPMs through communication with stake holders, supporting them by providing training on BIM.

VIII. FUTURE WORK

There is less exploration done in 'post construction benefits of a project while using BIM', 'risks regarding intellectual property' and 'technical interoperability issues of BIM'. In order to further this research, investigation into these could be done.

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APPENDIX A

- BIM - Building Information Modeling
- AEC - Architectural, Engineering and Construction.
- BE - BIM Expert
- SPM - Senior Project Manager
- VDC - Virtual Design and Construction
- VDC - Visual Design and Construction

APPENDIX B

Interview questions for Senior Project Managers and BIM Expert

- Introduction
  1) Within your organization, in which department are you working and what is your position/role?
  2) What is your responsibility in the projects you currently carry out?
  3) What is BIM means for you?
  4) How many years experience do you have with BIM?
  5) What is considered as success factors for introducing BIM?
  6) How many years of experience does your company have with BIM?
- Identification and management of BIM
  1) What aspects of BIM is your company currently implementing (Product (Building or plant),Organization, Design and construct and operate, Process ? How did you choose these aspects of BIM?
  2) How has BIM been introduced in other companies?
  3) What aspect should be the primary in the BIM implementation?
- Organization level
  1) What are the potential benefits with BIM to implement?
  2) What are critical factors in successful implementation of BIM?
  3) What issues and concerns are you encountering on projects that incorporate BIM in design? What do you think are the risks emerging with BIM implementation?
  4) Is there any interoperability (interoperability) in implementing BIM. How do you deal with the interoperability issues ?
  5) How much did it cost your company to get started with BIM? Have you tracked your return on investment?
  6) Have you concerns regarding model ownership when you are implementing with BIM ?
- Best Practices
  1) How did your company make the change in adopting BIM practices? Did it have a significant impact on your typical design process?
  2) Do you have a development plan for making change to BIM?
  3) In order to adopting this change what type of training company and you use?
  4) How do you get all parties of a design project to agree on new methods of working?
- Conclusion
  1) What do you think about the future of BIM and what is the current trend within your company toward performing more projects with BIM?

APPENDIX C

Search strings

- AEC
- Architectural
- Engineering
- Construction
- Adoption
- Industry
- Building
- Manufacturing
- Organizational
- Product
- Processes
- Digital representations
- 2D models
- 3D models
- Multidimensional models
- Visual
- Design
- Computer
- Aided
- Civil
- Engineers
- Architect

- Consultant
- Methods
- Data
- Information
- Effectiveness
- Practicability
- Information Systems
- Simulation
- Scheduling
- Prevention through design
- Planning
- Trends
- Challenges
- Benefits
- Risks
- Exchange
- Storing
- Sharing
- Interoperability
- National
- Foundation
- Classes
- IFC
- CAD
- IFDLibrary
- CSI OmniClass