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Current and future use of BIM in renovation projects

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

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CHALMERS UNIVERSITY OF TECHNOLOGY
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Abstract

In Europe, more than 80 per cent of residential buildings were built before 1990. For this reason, current and future construction projects increasingly focus on renovation all over Europe. On the other hand, developments and use of IT (Information Technology) have increased in many construction projects as IT has gained importance as one of the factors that determine the success or failure of a project in the construction industry. From the IT perspective, BIM (Building Information Modeling) has become more widely spread in the construction industry. In the UK, the Government Construction Strategy was published in 2011, which announced the Government's intention to require "collaborative 3D BIM" on its projects by 2016. However, although according to recent research, BIM is becoming popular in the whole construction industry for new buildings and is feasible to use in renovation projects, it has not reached its full potential yet.

The purpose of this thesis is to examine the current and potential use of BIM in renovation projects. A comprehensive literature review in combination with empirical data collection in the form of interviews has provided the basis for the research. The empirical data were collected through four semi-structured interviews with representative employees of four major construction contractors in Sweden. Interviews were conducted with one VDC Project Group Manager, one BIM Strategist, one Regional Manager, and one BIM Project Manager. Interviews provide insights into individual perspectives and gauge their experiences of BIM environment in renovation projects.

The findings of this thesis suggest that the current use of BIM in renovation projects is due to several factors. Although potential benefits of BIM are well known to professionals for new construction, there are still barriers such as little client demand, complexity of the renovation projects, and lack of skilled labor for the implementation of BIM for renovation projects. The result of the study highlights the possibilities for increase and improvement in BIM use in the future for renovation projects.

Key Words: BIM, renovation, information technology

Contents

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1 Introduction

1.1 Background

Since the early 1980's, use of computer technology in the construction industry has started with producing drawings. Developments in technology have led to models in 3D format and begun to increase in the 2000's with the purpose of visualizing buildings. In recent years, more information has started to be linked to models and thus, defining objects instead of a purely geometrical perspective. In that sense, BIM (Building Information Modeling) is increasingly being used for this original purpose in the construction sector.

Most researchers studying IT, software applications and data sharing methods are mainly focusing on new construction, whereas renovation related methods fall behind in terms of studies (Penttila et al., 2007). In today's construction sector, BIM is increasingly used in new construction but the question is how and where BIM is used and what its potential benefits are in renovation projects.

According to Volk (2014), BIM implementation both capabilities and challenges regarding the different stages of renovation projects. Especially, using BIM in the facilities management (FM) phase seems to have significant benefits regarding heritage documentation, quality control, energy and space management etc. In addition, using BIM in demolition processes has advantages such as offering up-to-date building information to minimize errors and reduce risks through data management, demolition scheduling, cost calculation etc.

Apart from its capabilities and challenges, use of BIM depends on the requirements and the methods chosen for the renovation projects. However regarding BIM and renovation projects, finding answers to several questions in which stages BIM is used (whether in design or production), what kind of information is associated with the model, is BIM used in specific parts, do all individuals have access to common model etc.) would help to improve the current status and future capability of BIM in renovation projects. It seems that there is today a necessity to consider whether it is a

matter of changing the behavioral patterns rather than developing the technology further.

1.2 Aim and purpose

The purpose of this study is to analyse the current practice of BIM in renovation projects in order to identify how and where BIM capability would be improved in renovation projects for future needs.

1.3 Research questions

Based on this purpose, the following research questions and sub questions are defined:

- How widely is BIM used in renovation projects?

Sub questions:

- Which features of BIM are used in renovation projects?
- Which individuals are taking part in the different stages of BIM use in renovation projects?
- What are the potential benefits of BIM implementation in renovation projects?

1.4 Limitations

This study is limited to the four different construction companies in Sweden. The investigation has been carried out from the time span between 1 February 2015 and 1 June 2015. Within the construction companies, one VDC Project Group Manager, one BIM strategist, one Regional Manager and one BIM Project Manager have been interviewed.

1.5 Disposition

The report begins with the theoretical framework on which the study is based. This section starts with difference between new construction and renovation regarding. The section continues with a broader view of ICT use in the construction industry, reviewing the concept of BIM, its focus and application areas in the construction sector and the development of BIM in the construction industry and ends with BIM's

capability and advantages in renovation projects. Thereafter, the methodology chapter is presented, a chapter that explains how the study has been conducted and the methods used to obtain the results that will answer the posed questions. This chapter is followed by the findings chapter which presents the outcomes from the interviews. The following chapters, namely the discussion, examines the relations between the introduced theory and the findings. The report concludes with summarizing the important points and presenting the main outcomes of the investigation.

2 Theoretical framework

This chapter consists of four main sections. The first part, Section 2.1 begins with a comparison of BIM use between new construction and renovation projects focusing on the design phase. The second part covers the development of IT use, the role and areas of IT in the construction industry. The third part, Section 2.3, introduces the concept of BIM, and then continues with the development and application areas of BIM in construction industry. The last part, section 2.4, continues with BIM in renovation projects highlighting capability, advantages, implementation and information sharing of BIM.

2.1 New construction vs. renovation

Renovation projects reflect about 1/3 of the total cost spent on construction projects (Singh et al., 2014). In addition to privately owned properties, increasing investment in renovation projects attract the attention of public owners and governmental institutions in order to improve and maintain their built and infrastructural facilities. In comparison to new construction, renovation projects offer an economically feasible alternative for public owners as multiphase renovation projects take out the need of close owner's operation during construction phases.

2.1.1 Design Phase in new construction vs. renovation projects

According to Singh et al. (2014) the volume of renovation projects is growing in the construction sector although their performance falls behind compared to new construction in terms of cost, time and quality. Several researchers have highlighted that renovation projects carry a number of risks and uncertainties which are different from those in new construction and which have an effect on renovation, project performance.

Renovation and new construction projects are have different characteristics in the design phase. The most significant parameter is the unforeseen nature of ultimate design choices. The design tasks need to be carried out with active communication during the demolition, site activities and rebuilding for renovation projects. For this reason, continuously changing on-site status on renovation sites makes it difficult to

have design solutions fully presented in CAD format. In addition to this, non-orthogonal geometric forms and diversities in renovation projects are complex and slower to introduce with CAD (Rajala & Penttila, 2006).

According to Volk et al. (2014) when compared to new buildings, many existing buildings are lack complete, updated or fragmented building information. These shortcomings might result from insufficient project management, uncertainties in phases, time losses or increases in cost in retrofit or refurbishment processes. Since existing buildings often suffer from lack of building documentation or other information due to limited updating processes, limitations of BIM use and barriers to BIM implementation are only to be expected.

2.2 The development of IT use in the construction industry

Considering the past 30 years, the role of IT in most industries has changed dramatically. In 1980's, the revolution in technology had an impact on IT within many core business activities. Today, information technology contributes to all the functions of management such as planning and organization of activities (Gaith et al., 2012).

Fischer & Kunz (2004) stated that in the past 20 years, developments in and use of IT had increased in order to manage and document the processes of the many areas in construction projects. In today's world, all the project information is stored in databases with the use of software tools or computer programs as well as being represented in many different formats for projects. Mainly, these tools tend to be general tools like spreadsheet, text-processing software, and discipline specific tools such as mechanical CAD programs.

2.2.1 The role of IT in the construction industry

IT policy for the construction industry has been recognized by participants globally in current applications. The primary use of IT in the construction industry is for communication and data sharing. Shen et al. (2004) stated that IT has gained importance as one of the important factors in the construction industry that determine the success or failure of a project. In the construction industry, practitioners use IT in

order to analyse, evaluate the performance of the design, delivery, design of organizations and other processes in construction projects (Gaith et al., 2012).

A study by Tuman (1998) highlighted the importance of IT use that prevents information overload resulting from communication problems with the data or between individuals and teams. Besides, IT with effective network collaboration helps to structure a strong feasibility for the projects through different teams consisting of members who are located across buildings, states and countries. Moreover, virtual project management teams have a better opportunity to gain control over the design process and changes by using IT effectively. From the project manager's view in the construction industry, efficient and steady computer networking technology provides success within virtual project teams (Gaith et al., 2012).

On the other hand, information and communication technology increases the collaboration, communication and information sharing process in construction companies. Miyatake and Kangari (1993) stated that IT should be taken into account as an important resource in the construction industry, and automatic flow of information sharing in a firm is one of the main aspects linked to information technology. In addition to this, IT organizations create value for firms and customers' expectations since they fulfill the needs of businesses. Furthermore, use of IT in the construction industry is expected to increase as organizations are beginning to notice that IT can be used to gain and maintain a competitive advantage. In the future, as the construction industry becomes more and more technology driven, implementation and investment in IT is expected to increase. However, most IT applications in the construction industry are used without accurate planning and estimation (Gaith et al., 2012).

2.2.2 Areas of IT in the construction industry

According to Schlögl (2005) the main purpose of information and communication technology is to deliver the right information at the right time and place. To be able to do this, the main method is to implement systems such as technology-oriented information management and computer-based information systems. This is required

to reach a high IT integration level that would increase value for an organization as well as taking the complexity of its application into account (Gaith et al., 2012).

Taking an early contribution from the 1990's, it was said that in many cases, technologies that are implemented in different industries effectively help to carry out the required tasks, but there was not a specific standard layout which would enable them to work in collaboration (Koulopoulos, 1995). Even earlier, Najafi (1989) stated that computer technology has changed dramatically in the 1980's. In addition to this, Najafi (1989) investigated computer applications for different activities in of the construction industry such as surveying, designing, budgeting, scheduling, cost control and equipment management etc. Another early investigation by Fereig et al. (1989) explained that developments and evolution of computers would increase the potential use for computers in the construction industry. Furthermore, it was found that personal computers are faster, more flexible, secure and effective which is beneficial for the construction sector as construction-related software enables more effective decision-support systems for the management of the construction company and its applications such as inventory control, payroll etc. It is still so that, engineering applications for the construction sector are used in scheduling, procurement, cost control, equipment management etc. (Gaith et al., 2012).

Mainly, computer technology for design purposes focuses on combining the computer characteristics with human vision. For the construction sector, this technology can be used to formulate 3D objects from 2D images. On the other hand, 3D/4D models enable the designer of the building to track project planning and operation as a graphical interface. In different construction processes, models can be constituted through which users can check different process conditions (Gaith et al., 2012).

Generally, 4D models link components in 3D CAD models including activities from the phases in design, procurement and schedule. These models allow the project stakeholders to track the construction projects over time on a computer screen and revise the planned or actual conditions of a project in terms of 3D CAD model for any day, week or month. Furthermore, 4D models help all the project members to understand and express their opinions on the scope of the project and corresponding

schedules in a timely manner. Implementations of 4D models provide an improvement of the project execution strategy, constructability, site productivity and resolution of time-space conflicts. In addition, 4D models are more helpful in projects, which involve many stakeholders, in projects undergoing renovation during operation and in projects with complex, tight site conditions. Mostly, general contractors are using 4D models, if at all, for the coordination of the workflow of their subcontractors, site logistics and checking of the project's overall process (Fischer & Kunz, 2004).

2.3 BIM

Building Information Modeling is a new concept, which has develop since the 1970's as, model-based on building process, information and management of data with digital tools. Although the major aspect is a geometrical 3D model of the building, BIM covers the whole information including design and construction processes as well as maintenance phases throughout the life cycle of the project (Penttila et al., 2007).

2.3.1 Concept of BIM

There are two common definitions of BIM. One of them is from the Construction Project Information Committee (CPIC) as "… digital representation of physical and facility characteristics of a facility creating a shared knowledge resource for information about it forming a reliable basis for decisions during its life cycle, from earliest conception to demolition". An other definition is from the National BIM Standard as " a digital representation of physical and functional characteristics of a facility. As such it serves as a shared knowledge resource for information about a facility forming a reliable basis for decisions during its lifecycle from inception onward'' (Gholami et al., 2013).

2.3.2 Development of BIM in the construction sector

According to Kim & Park (2013), Building Information Modeling is becoming popular in the AECO (architecture, engineering, construction and operation) industry since BIM has an ability to handle various problems in the construction sector such as environmental issues, high project costs and energy performance etc.

The increase in complexity in construction projects has led the industry to search for alternative modern methods of construction and design which would cope with this complexity. Suermann (2009) highlighted the importance of BIM use for construction managers and contractors, as well as designers, which enables them to complete tasks more efficiently. Another point is that there is an increase in client demand for BIM use from designers and contractors. One example is the UK government which stipulates BIM use for building and infrastructure developments. According to the Government Construction Strategy on BIM, BIM level 2 will have been fully required in all project information, documentation and data being electronic by 2016 (Gholami et al., 2013).

As we can see, there has been a growing interest in the construction sector in using Building Information Modeling in recent decades as it offers such advantages as saving of resources during design, planning and new construction (Volk et al., 2014). In the early 2000's, BIM modeling was presented in pilot projects for building designs. Initially, most researches focused on the development of preplanning, visualization, costing; clash detection and data management etc. Today, however, the main tools of design, architecture, and engineering professions are getting more into basic features such as structural, energy analysis, scheduling and tracking progress (Becerik-Gerber et al., 2011).

2.3.3 Focus and application areas of BIM in the construction industry

BIM is thus being widely used in the construction industry for documentation, visualization and coordination between consultants and engineers. Sometimes client requirements and scale of a project determine the use of BIM based tools in construction projects. Frequently, BIM based tools are used in large and complex projects. Through the process of the project, BIM becomes an important part for documentation to form architectural plans and enable information sharing in one place. Moreover, models that are structured using BIM, are used to revise data, which are created by consultants and to avoid conflicts. These models are often used for energy simulation and prediction, quantity takeoff, coordination of construction work and scheduling. Additionally, BIM is capable of structuring walkthroughs for all

stakeholders and clients for better understanding and implementation of projects (Sheth et al., 2010).

As we have found, BIM focuses on design, preplanning, construction and project delivery of infrastructure and buildings although recent research has started to move from a primary focus on new construction to refurbishment and demolition etc. In general, the application of BIM is influenced by different conditions in buildings and structures such as types of use (e.g. commercial, residential, municipal etc.), status (e.g. new, existing) and ownership (e.g. private owner, universities). These conditions affect the level of detail and other functionalities of BIM use in design, construction, and maintenance phases. Recent surveys highlighted that BIM is applicable to complex and larger buildings and used by the respondents of surveys in residential, commercial, healthcare and other building types (Volk et al., 2014).

The historical development of BIM has its origin in object oriented systems and parametrical modeling linking to CAD software. The main intention of BIM use is not limited to the design phase but it has developed to be implemented for actual construction process information such as material handling, scheduling and budget. In that sense, BIM is incomprehensive if it is used for only geometric modeling of the building and not covering other aspects (Penttila et al., 2007).

Sheth et al. (2010) stated that looking upon the characteristics of BIM based software, use of BIM from the initial stages in the construction projects would be more effective compared to other stages such as operation and maintenance. Still today, this appears to be basically true, although renovation projects constitute an important special case of BIM use in a late stage of the building life cycle.

2.4 BIM in renovation projects

Most research about ICT, software applications and data sharing methods is as we have seen focusing on new construction and studies of renovation related methods are lacking (Penttila et al., 2007). The impression given is that BIM is interrelated in the design, management and other processes of new construction, while less interrelated with existing buildings (Mascio & Wang, 2013).

2.4.1 Capability of BIM use in renovation projects

Gholami et al. (2013) claim that BIM is mostly accepted and encouraged by specialists using different tools in the construction industry. For the renovation projects, designers and contractors should be able to recommend BIM as it reduces environmental degradation and increases energy efficiency. BIM is mostly used for visualization, collaboration, energy simulation and prototyping.

Most of the time, parametric tools during the renovation process are reused for coordination, energy simulation and visualization. Based upon the capability of BIM, it provides extensive visualization and high quality rendering which are presented to stakeholders (Gholami et al., 2013). For this reason, stakeholders and clients with different levels of knowledge would have a better understanding of projects through these abilities, which are given by BIM. Effective use of BIM can be obtained if it is implemented from the initial stages of a project. However, it can be used during any stage such as maintenance, operation etc. Another advantage of BIM is to facilitate certificates for building environmental performance like BREEAM. Further, BIM saves time in the design phase compared to other options, and should be able to provide the optimal solution as well as the various simulations (energy simulation etc.).

For Gholami et al. (2013) one of the potential advantages of BIM in renovation projects is to estimate the energy performance of alternatives by creating models. From several studies in literature, it is clear that energy simulation has a vital importance in determining the performance of renovation projects. In that sense, implementation of BIM and providing early energy simulation could increase efficiency of renovation processes.

2.4.2 Advantages of BIM use in renovation projects

Lately, the expectations of tenants for buildings have become diverse and irregularities in the design of buildings have become wider (Park & Kim, 2013). Furthermore, in renovation projects, issues such as energy performance and sustainability become important to consider. In this context, current 2D models are not capable of handling complicated design and managing large, complex construction projects and

information flow throughout the whole process of the project. In addition to this, in order to avoid data conflicts and unnecessary works, there must be an appropriate management system.

Responding to current problems in renovation projects, many studies are conducted in the area of information and communication technologies. From this research, BIM emerges as a new ICT to solve problems and increase productivity also in renovation. One of the main benefits of BIM is to create an effective early collaboration between project participants. Furthermore, early involvement of contractors in the design phase makes it possible to take more straight decisions on cost estimation and arranging the construction materials. However, there are restrictions due to data transfers between different software tools and legal contract issues (Park & Kim, 2013).

2.4.3 Implementation phases and information sharing of BIM in renovation project

More than 80 per cent of residential buildings were built before 1990 in Europe and do not include building information and documentation in BIM format (Arayici, 2008). For this reason, implementation of BIM in practice is costly and mainly helps to recapture building information with reverse engineering processes in terms of 'points to BIM, 'scan to BIM' (Volk et al., 2014).

According to Penttilä et al. (2007) especially in industrialized countries, as new construction rates stagnate, implementing and planning of refurbishment and renovation measures in existing buildings become important. There are several tools for building capture and analysis such as tachometry, 2D/3D geometrical drawings, laser scanning but these tools need strong skilled personnel in order to model and plan for existing buildings.

In existing buildings, BIM implementation has other challenges and capabilities compared to new construction. In the FM phase, BIM use has benefits such as valuable documentation, quality control, monitoring, energy and space management and retrofit planning. Furthermore, renovation phases could also benefit from well-structured up-to-date building information in order to minimize errors and financial risks through

data management, cost calculation or optimization of renovation progress tracking (Volk et al., 2014).

3 Methodology

This chapter presents the methodological approaches in this report. First, the research design is described and then detailed explanation of empirical data collection and analysis methods are given in this chapter.

3.1 Research design

For researchers, the traditional concept of the research process starts with the theoretical knowledge taken from the literature (Flick, 2009). Bryman & Bell (2011) stated that semi structured interviews create more flexibility in the interview process. In this report, semi-structured interviews were conducted in order to structure practical work and answer the research questions.

Literature review was made in the areas of ICT use in the construction sector, more specifically on the concept of BIM. There were no limitations in reviewing due to the publishing dates of the articles.

This report has a qualitative research approach to interviews, which provide empirical data for the findings part of this report. Furthermore, this research approach is considered as a proper database for the research questions that involve a qualitative approach.

3.2 Data collection and analysis

The empirical data in this thesis were collected through face-to-face interviews, between February and April 2015, which each lasted between 20 and 30 minutes. The interviews were semi-structured. All the interviews were conducted in English.

The interview questions were based on the literature review. The questions were structured to identify current BIM features, roles and responsibilities of individuals, differences between new construction and renovation and potential benefits of BIM use in renovation projects. The interviews covered a mix of open and closed questions such as “do you use 3D Laser Scanning linked to BIM”, “who is responsible for updating BIM database” (see also Table 1).

Four interviews were conducted in Gothenburg/Sweden with participants from four construction companies in the Swedish construction sector. From each construction company, one VDC Project Group Manager, one BIM strategist, one Regional Manager and one BIM Project Manager have been interviewed. These interviewees were chosen because they were mainly responsible for and experienced in BIM and ICT departments in the construction company. Furthermore, considering the nature of interview questions, they needed to be answered by top level individuals from BIM and ICT departments rather than site or project managers.

Two of these construction companies, Skanska and NCC, were ranked 15th and 41th respectively in 2014 according to Engineering News Record's top 250 global contractors list. The other construction company, which is PEAB, is ranked second by the total turnover in Sweden, which Skanska is ranked in 1st place. The last company chosen for the interview is Veidekke. All of the four construction companies work internationally, implementing BIM more than small sized and regional construction companies in Sweden. In addition to this, those construction companies work on different sizes of projects including small renovation projects as changing façade, interior operations of the building etc. This is one of the main reasons why these companies were chosen for the interviews. From their annual report, in 2014, the number of employees are at least 6,000 for all firms.

The interviews were recorded and transcribed to confirm the notes taken during the interviews. The reason why the interview method was chosen instead of a questionnaire survey is that the topic is such a sensitive and new topic that all the response rate for to a questionnaire survey might be insufficient and irrelevant. In addition to this, the questions, which were asked during the interviews, need detailed explanation and examples. In this respect, a questionnaire survey would be inadequate. The interview questions are listed in Table 1.

Table 1. Interview questions

1) Which features of BIM do you use in refurbishment projects?

   a) Geometrical
   b) Database (waste, energy, HVAC, material quality etc.)
   c) Logistics
   d) Other

2) How do you think BIM use differs in new construction and refurbishment?
3) Do you use BIM during the entire stage of refurbishment?
4) Who uses the BIM database? (For example: Client, subcontractors, site managers, project managers etc.)
5) Who is creating and developing the BIM database? (For example: Site managers, project managers, BIM coordinators, subcontractors etc.)
6) Who is actually creating the geometrical model?
7) Do you use 3D Laser Scanning linking to BIM?
8) Which subcontractors are using BIM?

   a) Piping/plumbing
   b) Electrical Services
   c) Painters
   d) HVAC
   e) Others

9) Do subcontractors have their own databases?
10) Is capability of BIM use a factor for the selection of subcontractors?
11) Which benefits does BIM provide in refurbishment projects?

   a) Cost Optimization
   b) Time Optimization
   c) Increased collaboration and communication between stakeholders
   d) Reduce resource use and waste
   e) Other

12) Which uses of BIM are most common used in refurbishment projects?

   a) Documentation, data management
   b) Subcontractor and supplier integration
   c) Localization of building components, indoor navigation
   d) Other

4 Findings

This chapter presents the findings from the interviews, which constitutes the empirical data for this study. The chapter serves to provide an overview of the current BIM usage focusing on main features, areas, roles and responsibilities of individuals, integration of subcontractors, potential benefits and uses of BIM in renovation projects. The interviews were structured in order to assess and map existing practice of BIM implementation for renovation projects so as to identify current and potential application areas for BIM.

4.1 BIM usage in new construction vs. renovation

According to all interviewees, BIM usage differs with regard to new construction vs. renovation projects. Currently, BIM is more commonly used in new construction projects than in renovation projects. One of the main differences in renovation projects for Interviewee A is the fact that renovation projects block creativity as they are much more locked into an existing building compared to new construction. He added that they are focused on what they must do and that they have something to build on in renovation projects.

From another point of view, Interviewee B explained that BIM usage depends a lot of subject as if they are creating a lot of building components; BIM would be same as in new construction but if they are changing a lot in building structure that BIM would be different. At the moment, BIM creates more value in new construction compared to renovation according to Interviewee B. Interviewee C and D are mainly using more BIM in new construction but partly in renovation projects.

4.2 Current features and areas of BIM usage in renovation projects

All of the interviews were started with the main features of BIM usage in renovation projects. Regarding the question, type of the renovation projects was specified in the beginning as large renovation projects to interviewees instead of small sized. Furthermore, main features of BIM usage depend on the project type as all the interviewees stated in the beginning. Mainly, they are not using BIM for smaller sized

renovation projects. According to three interviewees, the main features of BIM usage are geometry and logistics in renovation projects.

4.2.1 Geometrical feature

As to the geometrical feature of BIM, the obvious method is to use 3D Laser Scanning to get a proper and better picture of the building by coordinating 3D geometrical aspects. Interviewee A pointed out the importance of 3D Laser Scanning in order to get the materials that they are going to use for the renovation project and this action allowed them to keep their budget in the right track. In addition to this, using 3D Laser Scanning regarding BIM gave the exact measurements of the components of the buildings which provided them with lots of advantages in their work.

On the other hand, when the drawings are pretty old for renovation projects, 3D Laser Scanning helps them to see the changes, improvements and modifications that were made in the past which are not specified in the old drawings. For Interviewee D, the geometrical feature of BIM was not clear as they do not commonly use BIM in all projects but according to him 3D Laser Scanning would be really efficient in the design phase in some projects.

4.2.2 Logistics feature

With regard to the logistical feature of BIM, the interviewees believe that BIM gives good visualization, high quality of input data and helps the logistic companies to deliver and put the materials into construction site properly. However, Interviewee D agreed upon the logistical feature as pointed out the design of the construction site is easier with this feature however they do not use this feature of BIM in renovation projects so often.

4.2.3 Database feature

The database feature of BIM is more commonly used for waste management than energy, HVAC or material quality. According to Interviewee A, they have an agreement with the waste companies that have a section on waste types in BIM, which help them to handle all kinds of waste properly. For the database of waste, Interviewee D was not sure if it is connected to BIM database or not.

4.2.4 Main stages of BIM use in renovation projects

Generally, BIM usage in renovation projects does not cover all the stages of the project according to interviewees. From the responses, recently the design phase has become the most common stage of BIM usage in renovation projects. For Interviewee C, BIM is used for clash control in the production phase in addition to the design phase.

4.3 Roles and responsibilities of individuals integrated with BIM in renovation projects

There are many different individuals who take part in the implementation of BIM. From the interviews, these individuals can be identified as client, architects, subcontractors, site-project managers and BIM coordinators. At least some of these individuals are mainly integrated with BIM database in renovation projects, if BIM is used.

4.3.1 Responsibilities of main individuals integrated with BIM

Mainly, clients use the BIM database for their interest in final results and interaction with the architects. Subcontractors use it for the work preparation as modeling, drawings etc. In addition to these two roles, site manager use it in the preparatory phase of the work, material handling, visualization etc. On the other hand, project managers use the BIM database to make estimations about budget-schedule especially starting from design phase. BIM coordinators who are responsible for the coordination and tracking use the BIM database in order to check whether every process fits the purpose or not. Apart from these areas, the BIM database enables proper estimation and procurement phase for renovation projects.

4.3.2 Main roles and responsibilities of creating and developing BIM database

According to all interviewees, BIM coordinators are mainly responsible for creating and developing the BIM database. BIM coordinators are key actors in the coordination and development of the BIM database while site-project managers provide information for BIM coordinators by sending measurement data to help in updating the BIM

database. For Interviewee B, a consultant could be the main responsible, depending on the contract type, used for a particular renovation project.

On the other hand, Interviewee C divided renovation processes into design and production phase and stated that contractors-consultants are mainly responsible for creating the database in the design phase while the main contractor coordinates the database and is mainly responsible in the production phase. With regard to the geometrical model for BIM, according to the interviewees, contractors and consultants (internal-external) are key actors in the creation of the model. Interviewee A explained that they are creating a geometrical model and converting it to a virtual building model by using various tools such as 3D Laser Scanning, photogrammetry etc. For Interviewee C, architects, constructors and sometimes subcontractors are helping to create the geometrical model in addition to other key actors.

4.3.3 3D Laser Scanning integrated with BIM in renovation projects

As it was stated in the beginning, 3D Laser Scanning is the most common digital tool that is integrated with the geometrical feature of BIM. However, Interviewee B explained that they tried to use 3D laser technology for renovation projects but it is not so common in their company. In addition to this, they normally have drawings when they start renovation projects so more or less use of 3D Laser Scanning depends on the project type, according to Interviewee B. He pointed out that for complex and special renovation projects, use of 3D Laser Scanning would be more efficient. Interviewee D expressed that they tried 3D Laser Scanning a few times in renovation projects but they are not using it in every project.

From another point of view, Interviewee C stated that they used 3D Laser Scanning but not so frequently. They mainly use 3D Laser Scanning to get the various data for the building. He also added that use of 3D Laser Scanning depends on client demands. If there is no demand from the client, they do not use it but he believes that they will use 3D more frequently in the coming years.

4.4 Integration of subcontractors with BIM in renovation projects

For the interaction between BIM and subcontractors, all the interviewees agreed on which types of subcontractors are using BIM during renovation projects. For all of them, these subcontractors are piping, electrical and HVAC.

4.4.1 Main subcontractors integrated with BIM in renovation projects

All the subcontractors have their own tools, which are (or rather can be) integrated with a BIM database. Anyhow, Interviewee B stated that painters are using BIM if they prepare a good estimate for them. In addition to this, rather than that the painter gives them a price for the work, they have to estimate the price, which would avoid waste. As a specific example for subcontractor interaction, Interviewee B explained that if they can give them much better data on the building, subcontractors do not have to measure every aspect, which would help them to save time and give them digital insight of the building, which would be a much better and accurate external source of data. Another specific point made by Interviewee B is that this interaction between BIM and subcontractors mostly depend on the BIM Level used in renovation projects. If the BIM level is higher, the integration and use of BIM for subcontractors would increase.

4.4.2 Use of database feature of BIM for subcontractors

When considering integration between subcontractors and BIM, another important point is whether they have their own database or not. Except Interviewee D, all interviewees agreed that piping, electrical and HVAC subcontractors have their own BIM database especially for the design phase. According to Interviewee B, they have a CAD database for the geometrical model in renovation projects. From their perspective, they do not need so much data from the subcontractors; mainly they need scheduling and planning data from them for other processes during the project. Apart from that, Interviewee C pointed out that the contract types determine if the subcontractors have their own database or not. According to him, if they are using design-build, the subcontractors have consultants either external or internal.

4.4.3 Capability of BIM use factor when choosing subcontractors in renovation projects

According to interviewees, when they are choosing their subcontractors, their capability of BIM use is not considered to be an important selection criterion in renovation projects. Mainly, there are classic subcontractors for the renovation projects who have a lot of past experience and a skilled team who do not use BIM. These subcontractors can handle these kinds of projects as their teams have more experience and background in renovation projects.

Interviewee B added that they require their subcontractors to deliver to a minimum BIM level, which their company are using in renovation projects and sometimes they are adding this requirement in proposals. On the other hand, he also agreed that this requirement is not vital for the selection of the subcontractors. Regarding the phases in renovation projects, Interviewee C expressed that capability of subcontractor's BIM use is critical in the design phase compared to the production phase in renovation.

4.5 Potential benefits and uses of BIM in renovation projects

There are many benefits of BIM for the construction sector. Usually, these benefits are greater for new construction rather than renovation projects in current practice. On the other hand, according to interviewees, BIM has potential benefits in renovation projects as much as new construction.

4.5.1 Main potential benefits of BIM in renovation projects

The most important potential benefits of BIM for the interviewees are cost-time optimization with the effective and accurate planning for the project. As Interviewee A pointed out, BIM increases collaboration between participants in order to keep every individual in the same picture. He also added that BIM helps to reduce resource use and waste in renovation projects. Taking all these benefits into account, we can say that BIM can create more value for the final stage of the renovation projects. For Interviewee B, cost and time optimization can be the most important potential benefits of BIM for renovation projects. However, as it was stated in the beginning, he pointed

out that they do not use so much BIM in renovation projects and mainly focus on new construction. In that way, he could not add any other potential benefits of BIM use.

Like Interviewee B, Interviewee C stated that for 4D-5D BIM, there are lots of benefits but it is not developed yet in renovation projects. Frequently, they are using BIM in new construction rather than in renovation projects. Furthermore, he agreed on the potential benefits of BIM in cost-time optimization and increasing collaboration. According to him, the crucial potential benefit of BIM is visualization. Finally, according to Interviewee D, the main potential benefit of BIM is that BIM is increasing collaboration between project participants although he is not sure about cost and time optimization as a potential benefit of BIM. He said that BIM could help to reduce resource and waste somehow for renovation projects.

4.5.2 Most common uses of BIM in renovation projects

The identification of the most common uses of BIM in renovation projects differ among the interviewees as it depends on whether they implement BIM for their projects or not. For Interviewee A, documentation, coordination of subcontractors, giving accurate measurements for suppliers and localization of building components are the most common uses of BIM in renovation projects.

Interviewee C stated that visualization is the main potential benefit of BIM use; he also agreed on the same aspect for the commonly use of BIM in renovation projects. He did not agree on documentation use but added that clash and defect control can be considered as another use of BIM for renovation. Unlike other interviewees, Interviewee D was not sure about these common uses of BIM as they are implementing BIM more in new construction than renovation projects.

5 Analysis

The findings from the interviews show that the current use of BIM in renovation projects is limited. However, there are different perspectives, which could be new and helpful to add value to the literature that is lacking of BIM use in renovation projects.

5.1 Main features of BIM in renovation projects

To start with, findings from the interviews support the statement of Gholami et al. (2013), that BIM is used mostly in visualization and collaboration in renovation projects. For visualization, 3D Laser Scanning is the key tool, which reduce risks and provides 'heat map' for the individuals, according to the interviewees. This is important, especially considering risks and uncertainties attached to the existing buildings, 3D Laser Scanning would play an important role to reduce them.

In addition, scanning supports and offers a solution to the problems identified by Rajala & Penttila (2006) and Volk et al. (2014), who highlight the uncertainties and lack of complete, updated building information in renovation projects. Thus, 3D Laser Scanning would be the optimal solution to these kinds of uncertainties. In renovation projects, the most frequent risk occurs due to uncertainties in the building plan. Even if there are old, missing or incorrect building measurements in the plan of the building, 3D Laser Scanning can fix these in order to minimize the risks. 3D Laser Scanning can reduce unnecessary costs, which might be resulting from finding alternative methods and tools instead of laser scanning.

5.2 New construction vs. renovation projects in terms of BIM

The argument for BIM use in renovation and new construction projects differs in the findings compared to what is said in the literature. This perspective is about the creativity element of BIM in renovation projects. While BIM offers options to use creativity in higher levels for new construction as it is more open to creating and modifying new settings in different stages, renovation projects are limited in terms of creativity. Creativity is limited in renovation mainly due to being restricted by the existing building components and floor plans which block creativity compared to new

construction. This dependence on the existing structure could provide insights when comparing BIM use in renovation and new construction.

5.3 Main stages of BIM use in renovation projects

According to Gholami et al. (2013), BIM would be more effective if it could be used in the initial stages in renovation projects. This claim is confirmed by the findings, as the design phase is the most common stage that allows BIM use. The reason why BIM is used mostly in the design phase might be that the design phase is the critical stage that carries different risks and uncertainties in renovation projects. Since BIM can be used in all the stages of new construction, awareness of BIM benefits in renovation projects would allow BIM to be used not only in the design phase but in other phases as well.

5.4 Roles and responsibilities of individuals integration with BIM

From the findings, the roles and responsibilities of individuals during BIM implementation would give different perspectives on the relation between BIM and renovation projects. The interviews show that individuals in different roles have different responsibilities and contributions to the project. All these individuals have to work in strong collaboration in order to constitute a valuable BIM environment. Furthermore, the interview findings support the idea that BIM can bring all the individuals into a common workplace and database in renovation projects as Gholami et al. (2013) thought in their study. Table 2. gives a better understanding of different individual roles and responsibilities in different stages.

Table 2. Different roles and responsibilities of individuals in renovation projects regarding BIM

Roles	Interested In	Design Stage	Production Stage	Operation Stage
Client	Final results, interaction with architects	*		*
Site Managers	Preparation of work, material handling, visualization	*	*	
Project Managers	Estimations about budget-schedule	*	*	
BIM Coordinators	Coordination, tracking of every process. Creating and developing BIM database	*	*	*
Subcontractors	Work preparation as modeling, drawings etc.	*	*	

5.5 Integration of subcontractors with BIM in renovation projects

The integration of subcontractors with BIM usage in renovation projects might be a challenging task and be restricted, judging by the interview findings. Firstly, not all subcontractors are integrated with BIM due to (weak) demand from the client. If this demand could be increased on the client's part, it would provide several advantages for renovation projects. However, renovation projects have their own specialist subcontractors who depend on the experience through many years. For this reason,

clients want to have less risk and not to involve much BIM use in renovation projects. Basically, this client attitude appears to block integration of subcontractors with BIM.

This approach could be resulting from the lack of knowledge and benefits of BIM use in renovation projects on the client's part. If the client was aware of the potential advantages of BIM, it would increase demand of BIM use for the subcontractors. From the findings, these advantages are saving time, giving digital insights to subcontractors and avoiding waste in renovation projects, which is vital.

In addition to this, working in a common BIM database would allow client, main contractor and subcontractor to work in strong collaboration and would enable them to achieve their aims regarding renovation projects. If the awareness of these benefits of BIM usage in renovation projects increases, then main contractors could involve more requirements of BIM usage in their project proposals.

5.6 Potential benefits of BIM use in renovation projects

The earlier literature and the findings of this report have similarities when looking upon the potential benefits of BIM use in renovation projects. Kim & Park (2013) mentioned in their studies that one of the main potential benefits of BIM use is to reach project goals with a strong collaboration in renovation projects. This argument is supported in findings as BIM is increasing collaboration between participants in order to keep every individual in the same picture. Due to the complex nature of the renovation projects and as there are many different individuals involved in them, strong collaboration is needed for better outcomes. BIM increases collaboration between all the participants and enables them to speak a common project language. Furthermore, there are many misunderstandings because of the faulty drawings, lack of visual support, and improper material handling in renovation projects. Such misunderstandings would be avoided with common use of BIM for different individuals.

Other important potential benefits of BIM use are cost-time optimization and reduced waste as Kim & Park (2013) brought up in their study. Since, renovation projects have high initial costs, BIM would be a solution to minimize such costs with effective

planning and accurate procurement for the project. For the time optimization, BIM is helping to create an effective early collaboration between project participants. In that sense, this approach would avoid time losses and risks, as increasing information sharing between participants in the earlier stages of the renovation projects would be high. Furthermore, waste generation is a problem in most renovation projects. For this reason, proper and effective waste handling is needed in order to prevent, waste and manage whatever waste that is generated. BIM would be helpful in managing waste on the renovation site as support for organizing logistics, separating waste types and structuring material handling.

6 Conclusion

The aim of this thesis was to examine the current practice of BIM in renovation projects in order to identify how and where BIM capability would be improved in renovation projects for future needs.

Findings of this report indicate that current status of BIM use is low and limited in renovation projects compared to new construction due to several reasons including client demand and unawareness of BIM. However findings suggest that BIM use is likely to increase in the future as individuals and clients are becoming aware of the potential benefits of BIM for renovation projects.

The limitations are mainly affecting the BIM integration in renovation projects. Findings of this report suggest that, although interviewees are aware of the potential benefits of BIM, their clients want to stick to traditional methods in renovation projects. That limits implementation of BIM. Interviewees believe that their clients are becoming aware of the potential benefits of BIM and that client requirement for and implementation of BIM will increase in the future.

Due to the complexity of renovation projects, BIM would be an effective tool to handle main problems and risks during the project. The findings showed that BIM is able to increase collaboration and coordination between individuals, which would be effective during the renovation process.

Although current BIM use is limited in renovation projects, findings indicate that certain features of BIM are suitable and can be applied more in the future. If these features of BIM are appreciated especially by clients, this will result in an increase in BIM use in renovation projects.

Finally, future research should involve a study of how to increase awareness of the clients and of the potential benefits of BIM integration and which actions could be taken in order to encourage more BIM use in renovation projects.

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