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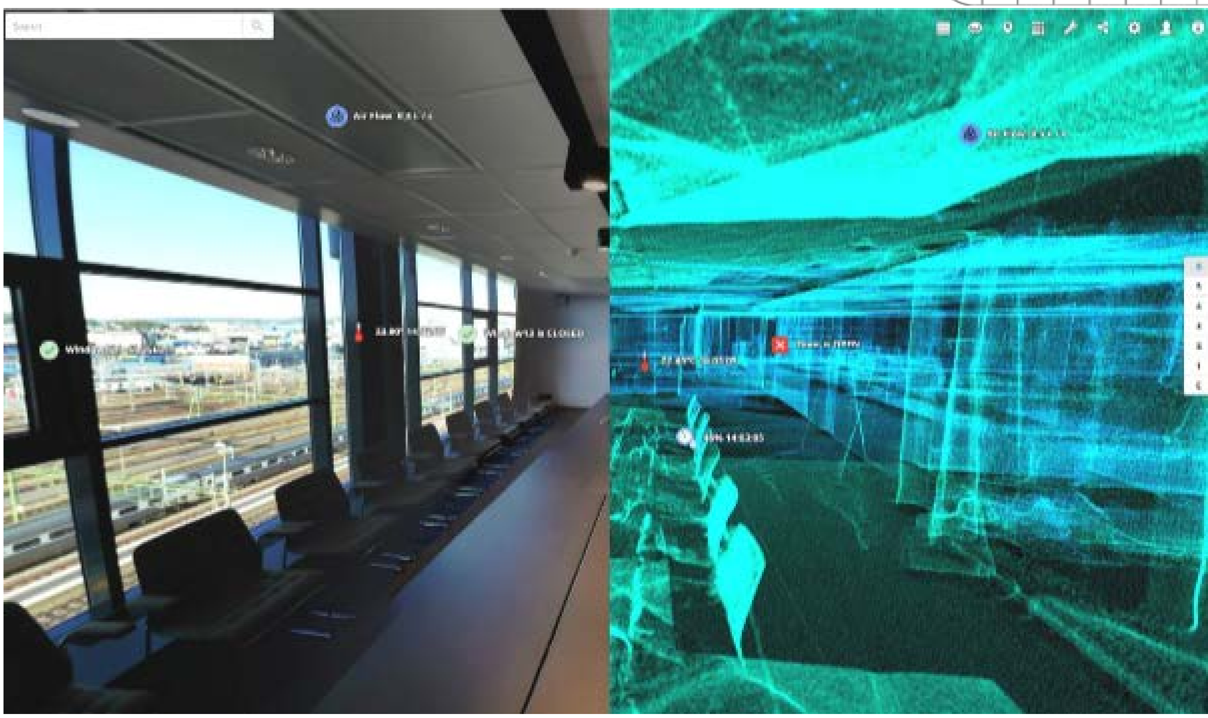

BIM for Existing Buildings

and its effects on Facility Management

Master's Thesis in the Master's Program Design and Construction Project Management

SHAFIQ MOHAMMAD
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Department of Architecture and Civil Engineering
Division of Construction Management
Master's thesis ACEX30-18-96
CHALMERS UNIVERSITY OF TECHNOLOGY
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ABSTRACT

The Building Information Modelling (BIM) is increasingly being used during construction projects. BIM is aimed to support the entire project life-cycle; from design to construction phase and the facility management (FM). However, BIM for FM is not reach yet its full potential usage. This paper is aimed to study and explore the value of BIM and the challenges affecting its adoption in FM application. The information handling which is required for efficient FM in the existing buildings and challenges to keep update the BIM information in FM.

Furthermore, the paper explores creating a BIM model in existing buildings with new tools and techniques such as laser scanning. This paper follows with theoretical framework, which is framing theory around the core subject of the paper, then it presents empirical data as findings which is collected by interviews and finally concluding the paper based on reflective analysis and discussions. The information is key which plays an important role for efficient FM and then throughout whole building life cycle (BLC). Hence through BIM, information is handled efficiently in the whole BLC. Through present technology such as laser scanning, creating a BIM model for existing buildings becomes easy and can produce fast and reliable data enrich model for existing buildings. An efficient integration of BIM and FM provides pre-assigned required maintenance and overall increase in efficiency in daily work of operations and maintenance. Through the integration of BIM and FM can achieve cost and energy saving. The key challenge will be fully automation of data update in the BIM model and its integration with FM.

Key words:
Building Life Cycle (BLC), Building Information Modelling (BIM), Facility Management (FM), Operations and Management (O&M), 3D Modelling, Laser Scanning, As-built BIM & As-is BIM.

Contents

Preface

This Master's thesis is the final project in our master's programme Design and Construction Project Management at the Department of Civil and Environmental Engineering at Chalmers University of Technology. It has been carried out during the spring of 2018. The study is started with initiative of our university supervisor, Mattias Roupé and Zynka BIM AB supervisor Daniel Månsson.

We would like to thank everyone who has been involved during the project. Special thanks go to our university supervisor, Mattias Roupé and Zynka BIM supervisor, Daniel Månsson, for all your guidance and support. We would like to thank all the interviewees, Petter Bengtsson, Anders Moberg, Jan Henningsson and Åsa Östlund, for openly sharing their experiences with us. We would also like to thank other group members who were involved in valuable discussions and contributed with important inputs. Without all of your contribution, this thesis had not been possible to carry out and your support is greatly appreciated, thank you!

Göteborg, May 2018

/Shafiq Mohammed & Sadik Ali Syed

Chapter 1 Introduction

1.1 Background & Purpose

In the past decades the Building Information Modelling (BIM) is increasingly being used during construction sector and BIM is also aimed to support the entire project lifecycle; from design to construction phase and the facility management (FM). However, BIM for FM is not reach yet its full potential usage. Taking this proposition as a beginning part, the purpose of this paper is to study and explore the value of BIM and the challenges affecting its adoption in FM application.

Information is the key factor for using BIM in facility management and such information can easily be managed for new buildings through whole building lifecycle (BLC). Existing buildings which are almost not BIM projects basically lack required information to the support of lifecycle of the facility (Volk et al 2014). The same argument can also be found into different literatures, Kassem et al (2015) argues that existing buildings currently don't have updated data and all too often the data is inaccurate. It is because the model has not been updated with any design changes made after the design phase or any changes which have been made during the lifecycle of a building and is therefore not an accurate model of the facility as it is built (Kassem et al, 2015). The author further argues that possibly the data is available, but it is not saved in a proper structure which makes it difficult to retrieve required data. Consequently, it is time consumption process to gather the required data which ultimately effects on efficiency (Kassem et al, 2015).

According to Volk et al (2014) BIM has concentrated on pre-planning, design and construction, but since recently it seems to be a research shift from the very early lifecycle of a building stages to maintenance, refurbishment, deconstruction and finally the end-of-life consideration especially of complex structures. In turn, this can provide a broad view on BIM & FM integration and its implementation not only for new buildings but for existing buildings which is not BIM projects.

Efficient FM requires adequate building information or documentation, but this often lacks for existing buildings, in consequence, inadequate information resulting in an ineffective project management which is time and cost consumption. Therefore, the information is the key success for existing buildings and more important is to collect, analyse and handle it in a proper way, that is utilized for FM and later building lifecycle phase. It is therefore required for the goal of this paper to focus on BIM model information about collection of data, analysis and convert/connect data from 3D models or point/photo scanning into a BIM model, and further usage of valid and structured data throughout the lifecycle of buildings for FM. Below Figure 1.1 shows our thesis's focused area of study.

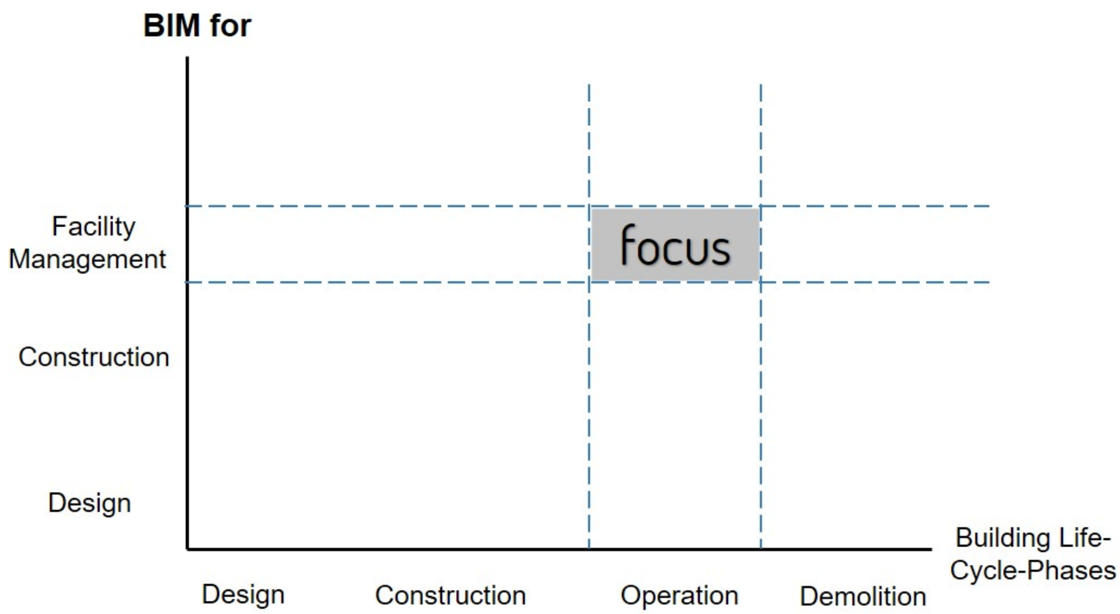

Figure 1.1 Focused area of the thesis: BIM for Existing Buildings and its effects on FM.

1.2 Objectives

During the lifecycle of buildings there has been given limited attention to facility managers and usually being included in the late phase of facility when the buildings are handed over to the clients. Accordingly, FM staff face huge problem during O&M phase of facilities. This indicates that the required data for efficient FM is either lacking or is inadequate, and this is a common issue for the existing buildings. Thus, BIM which is an important tool and an effective way of working for FM practice with the ability to keep the information/data up-to-date.

The main objectives of the thesis are to study BIM in later stage of BLC e.g. FM. The information handling is required for efficient FM in the existing buildings and challenges to keep update the BIM information in FM. And also creating a BIM model in the existing buildings at any point during FM for example at a point during the refurbishment of buildings.

1.3 Research Questions

1. What type of information is required to create a BIM model for FM in existing buildings? And how do we collect required information? By laser/photo scanning etc.

2. How do we convert or connect obtained information into a BIM model which can benefit the facility management?

3. How do we deal with such data in terms of up-to-date and then for further lifecycle of building?

1.4 Limitations

The major limitations of our thesis are explained below:

- Effective and quality BIM data and information for FM in existing buildings will not achievable until one has spent a lot of resources, money and time. So, our study has a major limitation about cost implication of creating a BIM in existing buildings.
- The ownership of data or information which is provided by BIM also a complicated subject to our study limitations.
- And other limitation is standardization of BIM data with specific codes, the difficulties and adaptability of new BIM evolutions in existing buildings and FM.

Chapter 2 Theoretical Framework

In this chapter we are going to frame our theoretical part in such a way that, first we start with brief introduction about the core topic e.g. BIM and FM in existing buildings followed by short description of different topics e.g. building life cycle (BLC), FM and BIM itself. Then we write theory in details description about creating BIM model in existing buildings and integration of BIM and FM.

2.1 Theory introduction

In the past decades a growing interest of using Building Information Modelling (BIM) had been increased in the construction sector, this is because of many benefits and resource savings during design, planning and construction of new buildings (Volk et al, 2014). Since buildings and structures differ in type of use e.g. infrastructural, municipal, educational etc., in age (new and, existing buildings etc.) and in ownership (e.g. Private owner, housing association, universities etc.) (Volk et al, 2014). The authors mentions that differing framework conditions are influencing the application of BIM and its supporting functionalities regarding design, construction, refurbishment, etc. due to stakeholder's requirements. As reported by authors, a BIM survey shows that BIM is suitable for larger and complex buildings which can be applied in residential, commercial, educational, healthcare and many other building types, but some groups e.g. facilities managers, owners which do not necessarily reflect current use of BIM in existing buildings (Volk et al, 2014) & (Becerik-Gerber et al, 2011).

When BIM Modelling was firstly introduced in pilot project, the idea was to support building design of architects and engineers. As a result, large research orientation started to focus more on the enhancement of pre-planning and design, visualization, quantification, costing, clash detection and management (Volk et al, 2014) & (Teicholz, 2013). In their reports the authors mention that the use of BIM which concentrates a lot on pre-planning, design, construction and integrated project delivery (IPD) of building, but since recently it seems to be a research shift from the very early lifecycle of the building to maintenance, refurbishment, deconstruction and finally the end-of-life consideration especially to large and complex buildings (Volk et al, 2014) & (Becerik-Gerber, 2011). On this account, it gives a broad view on BIM & FM implementation and its integration specifically not only to new buildings but to existing buildings which are not BIM projects.

On the other hand, the cultural approach to adopting new processes and technologies in the facility management (FM) industry is also considered a key challenge. The FM is quite rigid in its approach to new technology, though BIM for FM benefits are clearly proven (Kassem et al, 2015) & (Teicholz, 2013). There is also lack of demand by clients for BIM in FM and the lack of awareness by clients is declined by a shortage of BIM skills and understanding by FM professionals (Kassem et al, 2015). As a result, the above-mentioned factors together are creating a vicious circle interfering BIM adoption in FM applications. Existing buildings often lacks adequate data, accordingly, BIM implementation will rise a question on existing buildings for FM. At the same time, the authors argue that potential benefit of using BIM in facility management is rather significant e.g. as-built documentation, quality control, maintenance of warranty and service information data, energy and space management, assessment and monitoring, etc. They further argue that, BIM in FM application is an emerging area of research, suggesting that BIM information which generated and captured during the life cycle of building can make improvements on its FM, Volk et al (2014).

On the report of Volk et al (2014), BIM data for many existing buildings is either lacking or is inadequate for the FM purpose, due to this, inadequate building data/information might result in ineffective project management, time loss and cost increase in maintenance. Usually existing buildings lack as-built documentation because the model is no longer updated after it has been built or no changes has been made into the model during the life cycle of building, therefore the limitation of BIM for existing buildings are expected (Volk et al, 2014).

Moreover, new construction rates in industrialized countries maintains the same, this results in planning and implementing refurbishment and retrofit measures in existing buildings, (Volk et al, 2014). It is worth mentioning that, in Europe, 80% of residential buildings are built before 1990 and buildings documentation are not in BIM format (Eastman et al, 2011) or buildings constructed before BIM were introduced (Lu & Lee, 2017). Hence the availability and quality of "as-is" BIM information for the two different building groups e.g. new buildings and existing buildings can thus be different. Along with that, incomplete or even inadequate information in as-is files incurs a low level of efficiency in FM for existing buildings. As stated by authors, creating an as-is BIM for existing buildings is considered costly process and time-consuming, that require time and effort as well as skilled workers. For the purpose, to have an effective operation and maintenance of existing buildings, thus creating an as-is BIM is the foremost step only if convenient, efficient and economical approach with high accuracy is to be chosen, (Lu & Lee, 2017).

2.2 Building Life-cycle Perspective

The Building Life Cycle (BLC) is a process start with initiation of building concept till dismantling the building and its components. Basically, the BLC divided in to four phases: Design & Planning, Construction, Operations & Maintenance and Demolition phases (Su et al, 2014). The later phases after the construction phase and start using the building, we can refer as Facility Management (FM) phase in general. The Figure 2.1 shows the relation between the BLC and building functions (performance) and the cumulative cost throughout the BLC. Which also indicates, the design and construction phase is only up to 3-5 years, whereas FM phase may last up to 20-50 years.

Figure 2.1 The relationship between BLC and Building functions and the cumulative cost throughout the BLC (Su et al, 2014).

When it comes to Operations phase, it seems to be the costly phase of building lifecycle, and operation phase of the building is the main contributor to the building lifecycle cost (Kassem et al 2015). Study shows that the largest portion of the expenses happens during the operations phase (liu et al, 1994). Less than 15 percent of the total cost is comprised of design and construction, whilst the largest phase of building lifecycle, operation, forms approximately 60 percent of the total cost (Teicholz, 2013). This implies that over the whole life cycle of the building the biggest costs come from O&M (Becerik-Gerber et al. 2011), where a large set of activities during the operation is related to maintenance and repair of the facility.

2.3 Facility Management

There are a number of definitions of facility management, one provided by Spedding and Holmes (1994), define Facilities management (FM) as “an umbrella term under which a wide range of property and user-related functions are brought together for the benefit of the organization and its employees as a whole”. One that is oft-cited definition provided by Barrett & Baldry (2003), who see facility management as “an integrated approach to operating, maintaining, improving and adapting the buildings and infrastructure of an organization in order to create an environment that strongly supports the primary objectives of that organization”. Taking the importance of FM into account, utilizing the correct application of FM techniques will enable the firm to provide the right environment for carrying out its core business, this will result for end-user satisfaction and best value (Atkin & Brooks, 2015). It should be noted that applications of BIM for FM are fewer as compared to BIM adoption in planning, design and construction processes.

In order to understand how FM practices can effectively gain from BIM implementation, we should know what issues happen during FM processes for existing buildings, which cause lack of buildings documentation. Next section provides an overview about current FM practice for existing buildings and its problem when it comes to lacking adequate information for carrying out maintenance and operation of most facilities.

2.3.1 Problem with the current FM practice in existing buildings

According to Teicholz (2013), when one considers the wide documentation of information required for effective maintenance and operation of most facilities, it is clear that one should find efficient ways to collect, access and update this information is very important. For most existing buildings the information/data is stored in paper documents (rolls of drawings from architects and engineers, folder of maintenance records, etc.). And normally as per owners’ contractual request all the as-built documentation is handed over to the clients after the building is already in use, and sometime later stored in some basement office where it is difficult to access (Teicholz, 2013). Figure 2.2a and Figure 2.2b illustrate actual storage of FM documents.

Figure 2.2a Picture of document storage for FM information after turnover by the contractor (Teicholz, 2013).

Figure 2.2b Picture of document storage for FM information after turnover by the contractor (Teicholz, 2013)

As reported by Teicholz (2013), NITS published a study titled "Cost Analysis of Inadequate interoperability in the US Capital Facility Industry". This often-cited analysis of the cost impacts of the lack of data interoperability among different actors, and the bulk of the cost incurred by owners/operators, (for better understanding of the operation phase, see section 2.2). The reason summarized from the quote is; that an excessive amount of time need to be spent in order to specify and locate facility information from the previous work, e.g. as-built drawings from both construction and maintenance operation are not regularly prepared and the corresponding drawings are not updated after some changes has been made during later stages of building. In a similar way, information on the facility condition is difficult to locate and maintain, (Teicholz, 2013).

The author further mentions, documentation handling of existing buildings is done in a such way that usually at the end of a project, all as-built documentation is stored and archived in boxes and later handed over to the clients. And the documentation is rarely used or synchronized with a client's facilities management system, so with better BIM utilization throughout facilities, there is an opportunity to link the FM related information with building model. Accordingly, this will help to further visualize FM processes, with that the response time during maintenance call will be also considerably improved (Teicholz, 2013). According to Eastman et al (2011), case study for Maryland General Hospital indicating that, the FM information was mostly recorded on paper for the existing building and current processes had similar shortcomings; the life cycle of the equipment was not improved; warranty and other product information for current facilities was not easily available etc. Accordingly, the information on equipment was difficult to search because the as-built documentation was often outdated. Additionally, the current processes for the hospital building was completely informal and dependent on the knowledge of experienced staff members who worked for facility operation over the years. Consequently, the hospital spent a lot of resources on FM but didn't get results which is required. Later on, when BIM is implemented to the process, it offered an opportunity to record accurate as-built information, accordingly this helped to manage and maintain the facilities in an efficient way and increase BLC (Eastman et al, 2011)

As stated by McArthur (2015), when one considers BIM information for the aim of FM, it should be clear enough that the required information must be accurate, in this way it helps to maintain and manage the facilities in an efficient way and increase the lifecycle of the building. Moreover, it is essential for the creation of any BIM in operations model, that there should be the proper identification of the information necessary and beneficial to improve the operational performance of the building. On the other hand, when performing regular operations, one can find that there is no limit for the types of information included into a model, in other words, much of the information basically included in model is redundant for daily operation. Accordingly, the need for strategic identification of operational information is critical when a BIM model is established for operational data (McArthur, 2015).

According to McArthur (2015) problem occurs during FM, when it is highly required to create a BIM model for FM whereas no previous digital data exists, however there are also challenges related to modifying complete construction model. The author further mentions issues which arise during BIM creation model for FM practice and they are for example (1) the required operations and maintenance (O&M) data is generally not presented; (2) drawings in paper format are not updated during building lifecycle, (3) the file size can grow too large and is difficult to get the most important information out of it (McArthur, 2015).

As above mentioned, lack of data/information will result to challenge the BIM creation, however, there are tools/technique e.g. 3D scanning, that can be used to quickly develop a BIM model detailed enough to serve as the base geometry model, and image-based methods (Lu & Lee, 2017). On the other hand, as each 3D geometry is modelled an extensive site survey is also required to validate the available data, whereas site data-collection for existing buildings is considered time-consuming and expensive process that requires great effort, time, cost and skilled workers.

As mentioned in the previous section, implementation of BIM can significantly benefit FM. Nevertheless, creating BIM data for such FM requires intensive data, specific process and staff requirement. In this regard, in the following section BIM concept is explained.

2.4 Building Information Model (BIM)

To proceed further to the core of the topic, it is required to shed some lights on BIM information and its concept. The following section defines BIM and its concept generally in buildings, next BIM concept in building and its model practicing at different stage of BLC will briefly be discussed and finally creating a new BIM model in existing buildings will be explained in detail.

2.4.1 Definition and Concept

International standard defines BIM as “a shared digital representation of a built object [...] to facilitate design, construction and operation processes to form a reliable basis for decisions” (ISO 29481, 2016). According to Buildingsmart (2018), a building information model is a shared knowledge resource for information about a facility forming a reliable basis for decisions during its lifecycle; defined as existing from earliest conception to demolition. BIM has been broadly used as a platform to increase design team’s capabilities to organize building documentation, to monitor construction works as well as managing facilities during different operational stages of building in an integrated and systematic way (Eleftheriadis et al., 2017).

It is also considered as a perspective to assist the construction industry to develop new way of thinking and practices. According to Eastman et al (2011) BIM represent a virtual model of a building over the whole lifecycle (LC) by having enrich geometry and data, digital building models. According to Lee et al (2006) BIM is known with object-oriented software and includes of parametric objects indicating building components.

According to Wong & Yang (2010) three major types of information includes in BIM object; geometric, semantic and topological information. Geometric information directly relates to the building form in three directions, semantic information describes the properties of components, and topological information is about location of objects. It is argued that the information stored in BIM contains both geometric descriptions and non-geometric attributes e.g. semantically rich information, (Sanhudo et al, 2018). According to NIBS (2016) “BIM is 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”. Broad differentiations of BIM are 3D which is a spatial model with quantity take-off (Volk et al, 2014), 4D BIM (plus construction scheduling) which adds an extra dimension of information to a project information model in the form of scheduling data and, 5D BIM (plus cost calculation) with the ability to extract accurate cost information, 6D BIM (project lifecycle information), (NBS, 2017).

2.4.2 BIM models in Construction

Many companies are following using different BIM models for different BLC stages such as BIM Design model, BIM Construction model, BIM As-built model and BIM FM model (Haines, 2016). These models are keep evaluating or updating the previous BIM model through its BLC or created at a point where it required in case of existing buildings. Froese (2010) argues that in the near future, BIM will be used to virtually construct an entire project through simulations before it is erected or constructed in reality. The fact that BIM can be used to model buildings, and for the analysis to be performed virtually before the buildings is erected on-site, is one of the most important strengths of BIM.

From the blog article, the evolution of a BIM for FM by Haines (2016), Figure 2.3 shows different types of BIM models evaluates over time. As shown in Figure 2.3, BIM Design Model developed by design team with a level of development (LOD) to relay design intent and generate documentation and details used during construction. BIM Construction Model contains high level of details used before and during the actual construction to reduce uncertainty, improve safety, eliminate conflicts and stimulates real world outcomes. BIM As-built model contains both construction and fabrication data with detailed geometry and multiple disciplines aggregated into a single model that facilitate from AEC (Architecture Engineer & Construction) to owners. BIM FM model contains a level of accuracy that the design model but with updated as-built conditions for space and assets used for operations and maintenance (Haines, 2016). The BIM for facility model which is updated regularly during O&M can referred as “as-is” BIM.

Figure 2.3 Evolution of a BIM (Haines, 2016).

According to Haines (2016), there are two types of primary methods for gathering and creating a data rich BIM model in existing buildings. The first method is leveraging BIM data for post construction within FM and creating a link between BIM model and FM systems like Computer Aided Facility Management (CAFM) or Integrated Workplace Management System (IWMS). And the second method involves in creating a BIM model for existing facilities and creating a link with FM systems. It is an important aspect of embracing a holistic and comprehensive approach to BIM for entire BLC and it creates the value that BIM provides to facilities in existing buildings (Haines, 2016).

According to the author BIM shouldn’t be considered as a simple 3D CAD tool, but is rather similar to a database that enable a wide range of information about the attributes of different building elements and the relation among them (McArthur, 2015). And, it can provide a data-rich, object-based, intelligent and parametric digital representation of the building (Wang & Cho, 2014). Such database of information can vary between various phases of building e.g. design, construction and can be kept updating until the end of BLC. BIM technology not only concentrates on creating a simple 3D models, but also enable an intelligent platform to meet various stakeholders’ need. BIM have also successfully benefited design and construction processes for new buildings (Eastman et al., 2011) but recently BIM focus expanded to operation and maintenance phases or even retrofitting phase (Lu & Lee, 2017).

2.4.3 Creating a BIM model for existing buildings

In this chapter in brief about BIM model for existing buildings will be presented and we didn't focus on deep into methodologies, processes and procedures rather it is focused in brief on new technologies & tools and their usage & limitations. Through this we try to understand the automatic recreation of building on digital platform which is a data rich BIM model.

In literatures, lots of reviews and research on BIM implementation exists in a large number for new buildings (Teicholz et al, 2011) & (Wong & Yang, 2010) & (Liu & Issa, 2012). Whereas, use of BIM for existing buildings are thought to be fairly neglected (Volk et al, 2014) and less attention has been paid to BIM's application to manage asset and facility for buildings (Wong & Yang, 2010). Consequently, information which is lacking or even incorrect information in as-is records is regarded a primary reason for the low level of efficiency in FM for existing buildings (Liu & Issa, 2012).

According to Volk et al (2014) BIM creation process can be varied between for new and for existing buildings because of various building information quality, information availability and functionality requirements (Volk et al, 2014). Different BIM creation processes for new and existing buildings are illustrated, see Figure 2.4. For new buildings, named here as "as-planned" BIM is created in a process over several LC stages, starting from inception, brief, design to production. The BIM model is created in an interactive, iterative process by help of software and kept updating to an "as-built" BIM [case I] (Volk et al, 2014). On the other hand, BIM in existing buildings depends on the availability of pre-existing BIM, so BIM can be either updated [case II] or created a new one as a "points-to-BIM" process is carried out [case III], (Lu & Lee, 2017) & (Volk et al, 2014). To simplify, if the pre-existing BIM or as-built BIM available for the FM, then the process will be kept updating for the as-built BIM to maintain "as-is" BIM through adding valuable information of FM after each activity of O&M. If there is BIM data for existing buildings or as-built data exists for any building, then the process of planning, refurbishment and deconstruction of existing buildings might be done with smaller adjustments. If the pre-existed BIM is not available for existing buildings, in such a case, it is required to create a new BIM and then keep updating the information in BIM model. The authors further argue that if there is an outdated or no BIM available then the procedure begin with building auditing, documents review and analysis of previous and current building properties in order to prepare a profound basis for planning and cost estimating (Volk et al, 2014).

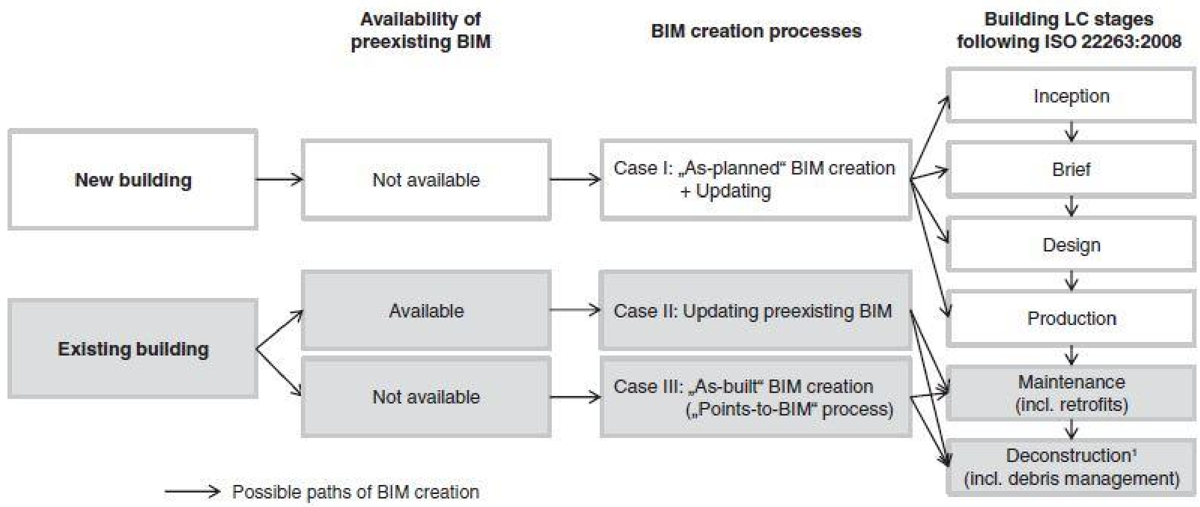

Figure 2.4 BIM model creation processes in new or existing buildings depending on available, pre-existing BIM and LC stages with their related requirements (Volk et al, 2014).

Creating a new BIM for existing buildings is not an easy task, because the difficulty is to gather geometrical and topological information of a building components and most of its components conceals by finishing walls and ceiling, etc. Authors further explain that the components are generally not fully visible or observable in existing buildings, even many elements will be totally hidden (Nagel et al, 2009). One way of creating a BIM is to develop a 3D model from old 2D drawings through computer programs like within CAD, Revit or other CAD software. These models generally consist of geometry and appearance information but do not represent thematic information and the meanings of the object, and thus they cannot be used for BIM applications (Nagel et al, 2009). Nevertheless, one can manually add the information like specifications from construction or contract documents to each object or element of building. In this process, it requires skilled and experienced person to create the model, which usually takes long time to update the information to created 3D model. Even after creating a new 3D model this can't refer as an As-built BIM model unless the model is not updated, because lot of changes occurred during construction and O&M phases. Therefore, the 3D geometric models represent the built environment as designed rather than observed (Nagel et al, 2009). Anyway, to collect information site surveys (e.g. tradition measurements) is required to gather reliable information of each element and update manually to created 3D model. In such a case, a lot of resources required and such a manual field surveying is rather labour-intensive, time-consuming and error-prone work (Jung et. al., 2014).

So, it would be efficient to look for reliable, quick and economical appropriate tools and techniques to gather building information as is condition from site and transforms into a BIM model. Authors Lu & Lee (2017) reported that there are different digital tools for capturing building information are available e.g. laser scanning or automatic locating of images, image-based method (Lu & Lee, 2017). Regarding geometric data acquisition the report mentions that the recent technological developments made it possible to generate 3D models to assess as-built condition. These technological expansions enable the capture of the as-is building in details, allowing for a more precise BIM model and a better analysis of retrofitting projects, (Sanhudo et al, 2018). With these available new technologies such as laser scanning/point-cloud and photo scanning one can gather information quickly and transform information into a BIM model. Laser scanning and point-cloud surveying techniques which can produce point-cloud data for existing buildings, the cloud data can be linked to BIM objects that can be used for designing, renovation or retrofit work, (Eastman et al, 2011). On the other hand, existing buildings can take advantage of BIM concerning documentation, visualization or facility management if a reliable data capture technique can provide as-built BIM at an appropriate cost and time (Volk et al, 2014)

According to Brilakis et al (2010) laser scanner are used to capture the data of a building as-built condition. A laser scanner returns data as a point cloud, visualized through commercially available software, which users can interact with, manipulate and immerse in allowing for construction as-built conditions in a virtual environment. Laser scanners have the capability to collect data very fast, and the quality of surfaces generated by this method is relatively high (Brilakis et al, 2010) and laser scanning directly collects metric 3D information in just single scanner setup (Jung et al, 2014). Laser scanning is gaining rapid acceptance in the AEC industry for support of 3D as-built BIM creation, because it provides significant advantages over traditional approaches especially by facilitating design and construction activities on the basis of accurate and fully representative 3D point cloud data (Jung et al, 2014).

According to Jung et al (2014) laser scanning process required a series of post processing steps; (1) Data collection in which the dense point cloud data of target structures are collected using laser scanners. (2) Data processing in which the point cloud data are filtered and registered as a single point cloud in a common coordinate system. (3) Geometric modelling in which 3D building components are reconstructed as a simplified representative 3D shape. And (4) Creation of BIM in which low-level surface model is transformed into a semantically rich BIM by assigning an object category, material properties and topological relationships between objects (Jung et al, 2014). For more information and pictures illustration see appendix C.

Laser scanning appears to be the most promising, most accurate as well as less time consuming and it can achieve a 3D position accuracy of 6 mm at 100 m range (Sanhudo et al, 2018) (Geosystems, 2016). Despite this, as stated by Sanhudo et al, (2018) several existing as-built survey technologies such as laser scanning, 3D camera ranging and photogrammetry were re-viewed by different authors and they concluded that these technologies all need expensive equipment, knowledgeable staff and is time consuming. Similarly, Bhatla et al. (2012) mentions key limitations related to the expensive equipment as well as the requirement for knowledgeable operators. Laser scanning which basically generates point cloud and the advantage of the organized point cloud is that data processing more efficient by knowing the relationship between adjacent points or nearest neighbour (Wang & Cho, 2014)

However, many proposals for process and methods with new technologies to create As-built BIM in existing buildings produced by different literatures, but still current technologies are at semi-automated and not achieved complete automation for creation an as-built BIM. The authors mention that the chief limitation of current indoor 3D BIM creation to be the still-incomplete automation of the laser scanning process (Jung et al, 2014).

To summarize this chapter, As-built BIM creation for existing buildings involves three steps, first, geometric model of components, second, attribution of categories and material properties to the components and third, establishment of relationship between them.

2.5 BIM & FM

It is argued that the largest amount of the lifecycle cost of a facility occurs after the construction of building is completed (See Section 2.2 for more details). BIM can gather and manage information throughout the whole building lifecycle (BLC). Such information can efficiently be used to improve the management and operation phases of a facility's lifecycle. The following section provides information on the topic *need for BIM in facility management* next *integration of BIM and FM* will be discussed.

2.5.1 Need for BIM in FM

The opportunity of using BIM in facility management is rapidly becoming an interesting area of research focus (McArthur, 2015), and yet using of BIM during building operation and maintenance is falling behind the BIM implementation for design and construction. It is worth mentioning that throughout the lifecycle of facility the largest amount of expenses occurs during the operation phase, where less than 15% cost accounts for the total cost occurs during design and construction, whereas the longest phase of BLC, operation phase accounts approximately 60% of the total cost (Teicholz, 2013). As reported by Eastman et al (2011), BIM tend to collect, share and manage information through the whole BLC. Research shows that the architecture engineering and construction (AEC) industry have encountered some savings in the early stage of facility lifecycle alongside with fast delivery and with fewer change orders through usage of virtual building modelling and analysis approach (Smith, 2007) & (Valentine and Zyskowski, 2009), whilst there would be an opportunity for greater savings during the operation and maintenance stages (Smith, 2007). Though the majority of costs occurs during the operational and maintenance (O&M) phase, yet buildings are currently driven by short-term construction savings rather than long-term operational savings (BIMhub, 2018).

According to Gu & London (2010), the ability to support FM is an important value-added feature for the BIM approach. The information which is stored in the database during the project is helpful for later retrieval of facilities. The database can be updated throughout BLC and can identify the information required for maintaining the building facilities. Implementation of BIM suggesting to provide a reliable facility information database and integrated views across all facility system, through which facility managers retrieve and analyse information about the entire system. BIM, if it is compared with traditional data representation formats (paper, 2D/3D CAD), can provide all building information being stored in one model, and all stored information in this way helps integrated views among multi-stakeholders e.g. owner, designer, architect, engineer, contractor. The authors further mention that BIM can provide 3D spatial information about buildings and its system, hence it has the ability to support visualization and spatial analysis of different maintenance activities occurring in a facility. Such situation might not be as easy to be performed with traditional databases (Gu & London, 2010).

As previously mentioned, information is key in BIM, Figure 2.5 shows how information transfer throughout BLC. According to Su et al (2014), from the Figure 2.5, the blue line shows the information transfer through BIM and yellow-red line shows the information transfer through traditional way of information handout from one phase to another, such as drawings, contract documents, files, warranty etc. The grey area indicates the overall loss of information.

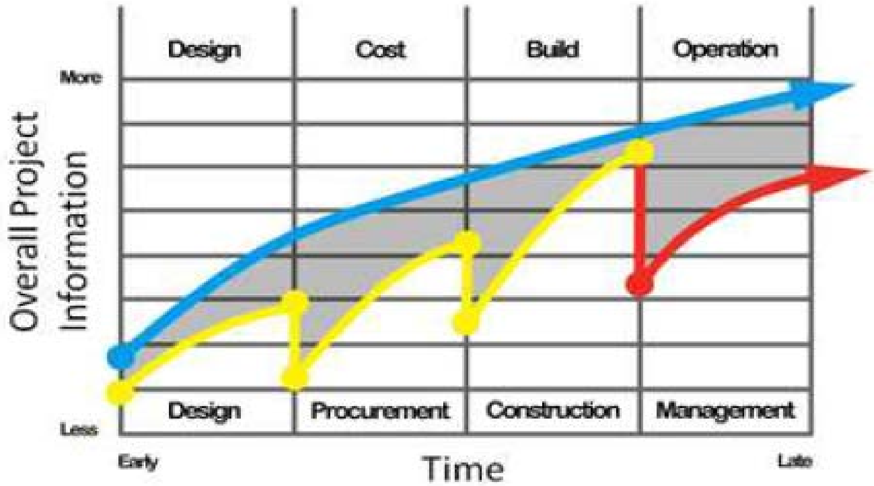

Figure 2.5 BIM information transfer (Su et al, 2014).

The authors Eastman et al (2011) mention in their report, to perform efficient maintenance, FM staff must regularly locate building components such as (equipment, materials and finishes) and its corresponding information for quick problem detection and resolution. Traditional way of performing FM, onsite FM staff relies on paper-based blueprint (mainly incomplete drawings during BLC) or on their experience in finding and locating building equipment e.g. electrical lines, ducts, water pipes and gas which are not easily visible particularly under the floor or above the ceiling or behind walls (Eastman et al, 2011). One should consider that locating such an equipment is a repetitive task which is time and labour consuming task for the FM staff. Further, locating the equipment become more critical during emergency. In addition, locating equipment also become difficult task when newly/outsourced FM team take charge of the facility. Or in such a case, when the equipment being changed or removed without notifying the FM staff in charge, (Becerik-Gerber et al. 2011). Accordingly, lacking adequate information which is a need to carry out FM related work, makes it delay in performing daily work which is rather costly. Therefore, an “as-is” or an “as-built” 3D BIM model is utilized to show where plumbing, mechanical and electrical components are in facility, which this enables the location of the equipment onsite and delivery/display of data relevant to the operational context (Becerik-Gerber et al. 2011). Moreover, by utilizing BIM tools, onsite FM staff can direct into BIM models and use BIM functions (e.g. search, view, find, highlight, filter, etc.) and can easily guide themselves to the aimed component e.g. location of the plumbing and other operational work.

The authors further mention that most existing O&M processes do not automatically pre-assign require maintenance for equipment, because the FM staff do not have a proper schedule for facility activities. Warranty and other related information on equipment is not available to efficiently perform their work. Maintenance can only be done on daily/monthly bases and not to be done according to the equipment’s actual need. Additionally, often repairs done by FM staff without knowing if there is need or not, because status on repair is unknown for the FM staff itself to search the previous record for O&M work (Eastman et al, 2011).

Issues that the FM is confronting over the BLC, the BIM technology in general provides opportunities for members to control and facilitate their daily work. For instance, BIM combined with navigation capabilities can navigate the FM staff to the desired components, just like global positioning system (GPS) connected to maps in outdoor environment (Becerik-Gerber et al, 2011). On the other hand, if FM staff is provided with a mobile or other digital devices that support better navigation tools and other FM functions, will better reduce FM staff dependency on the office staff and/or paper-based systems. Consequently, the FM staff will quickly access to their daily work, equipment failures will also be reduced that cause emergency repairs and impact tenants (Teicholz, 2013). As stated by Becerik-Gerber et al (2011), a linkage from BIM to FM database can help to find and diagnose building equipment with attached relevant information (e.g. product warranty information and maintenance history) which possibly be automatically connected with the located equipment and sent the information to the on-site staff. Accordingly, FM staff will get the right information at the right place, and based on the information they have at hand, will reach to the right decision.

With BIM utilization, the field personnel access the information in the field while inspecting the equipment, updating the records with new/replacement equipment information. The information is updated and synchronized with the central database. All information which is stored in the central database will be available all the time, this will help to eliminate waste for FM and increase the lifecycle of the equipment, maintenance prevention will be also increased, reducing waste from incorrect replacing the equipment which is yet covered by warranties or other contract service for the equipment, and finally accurate as-built documents will have provided, (Eastman et al, 2011).

With the BIM utilization there is opportunity to automatically show which components in building should be repair (because of different reason e.g. expiration date might have finished, or some equipment need proper maintenance). When reparation process is done for the equipment it is then recorded into the database with all necessary information which is required for next O&M work. Thus, the process become very efficient and with all required information at hand the FM staff can easily make a decision, (Eastman et al, 2011).

According to the United Nations Environment Programme (UNEP, 2015) buildings are the largest global consumer of the energy. Most of the energy used by any building is consumed during the operational stage of the BLC (Guo & Wei, 2016). Increasing energy efficiency and reducing energy consumption are some of the focal study objectives in the AEC Industry, (Sanhudo et al, 2018) and it almost always means increasing cost, (Guo & Wei, 2016). Moakher & Pimplikar (2012) mention that BIM has the capabilities to assist its user in achieving a more energy efficient building. Researchers have also discovered the possibility of using BIM to simulate energy consumption, (Crawley et al., 2001) and the data generated from such simulations can be used to create more efficient design alternatives in a quick and cost-effective way, (Abanda & Byers 2016).

With the increasing demand for energy efficiency, BIM has the potential to benefit energy analysis. By utilizing BIM as a data source for energy analysis, the data input will be more efficient and the existing data more reusable for the BLC, Laine & Karola (2007). As stated by Sanhudo et al, (2018), BIM utilization is used to model buildings and to sequentially perform multiple analysis, this will enable the energy performance prediction of various retrofitting measures in existing buildings, which in turns enable one to further compare different design alternatives and then to make an improved final decision.

According to Natephra et al (2017), The World Energy Council (World Energy Resources 2013 Survey, 2016) estimated that buildings accounts for almost 40% of the total global energy consumption. According to Abanda & Byers (2016), heating and lighting systems which are two major factors that influences energy consumption in buildings. In addition, the authors further state that the major amount of the total energy demand for building is electricity for lighting, e.g. lighting energy consumption 40% in large office building in china, 16.7 % in US for commercial buildings and 40% in commercial buildings in Japan, (Natephra et al 2017). Here utilizing BIM and its simulation tools assist the designer in making better decisions to reduce energy consumption and create better lighting conditions for occupants and improve building energy efficiency and overall building performance. This in turns will make a huge contribution toward lowering the energy demand for buildings.

2.5.2 Integration of BIM & FM

BIM FM integration according to Teicholz (2013) when done correctly, can provide very significant owner benefits. These benefits come when collection of data is saved over the design and construction processes rather than waiting until the completion of the building. Moreover, the smart usage of a digital database of building information will allow the FM managers and staff to make better and faster maintenance decision and provide higher quality performance. And the same database with stored building information can also support more informed use of the building and its modification over its life (Teicholz, 2013).

According to the survey made by The British Institute of Facilities Management, reveal that BIM has the potential to deliver significant benefits to the facilities management industry. And 83% of the survey respondents (the responses were from the UK as well as across the globe) agree that BIM has the potential to deliver significant added value to FM. Moreover, survey shows that a higher number of questionnaires (91.7%) had already heard of BIM with (83.4%) of the questionnaires believing that BIM will help in order to support FM. 74% thinking that BIM will significantly influence on the FM industry with 83.8% indicating that BIM is already having an impact or will do so in the next five years (Ashworth & Tucker 2017).

Specific technologies such as point-cloud, 3D scanning and RFID tags (Lin et al., 2014), have made it possible to adopt and added value to BIM in a FM operation (McArthur, 2015). BIM also allow capturing and transferring facility-related information to Computerized Maintenance and Management Systems (CMMS) and/or Computer Aided Facility Management (CAFM) Systems (Akcamete et al, 2010). Such a system namely COBie (Construction-Operations Building Information Exchange), is an information exchange specification which creates a platform for engineers, architects, contractors and manufacturers to input data in computer interpretable format at the early stage of building lifecycle. Information users at the downstream utilize the same data and do not need to recreate or re-collect the required facility information (East, 2007).

According to Teicholz (2013), interoperability is key for BIM & FM integration, because all of the data is apparently not entered into one system, therefore interoperability of system is required so that data can be communicated and flowing from upstream system to downstream use. It is further expressed that different ways of achieving flow of data and their integration exist e.g. (1) in this integration of systems, users create a spreadsheet to capture equipment and the related data that is needed for FM and then the information is entered to CMMS system through import option.

This approach seems to be easier to implement on small project but it has high errors, there is no validation of the data being entered. (2) Using COBie standards which does not require integration with BIM as the COBie data can be imported into a CMMS program. This option does not provide a graphic data in order to show location of equipment. (3) Two-way links system between BIM modelling and FM support system (4) directly integration of CMMS system with a BIM modelling using BIM application programming interface (API). This is an effective integration of the two systems where graphics data is updated in BIM while FM data is entered into COBie and/or directly into the CMMS system. Most importantly, another option in which data content is supported by cloud-based server and can be accessed anywhere using a browser (Teicholz, 2013).

COBie has the capability of retrieving essential information from BIM data, including maintenance plan and system instructions with help of spreadsheet format and then importing facility data to other computerized system like CMMS (East et al, 2009). Through utilization of COBie application during operation and maintenance phase, it decreases the need for recapturing and re-creating the facility information by architects, engineers and contractors (Gallaher et al, 2004), which results in saving a huge amount of money during O&M.

According to Teicholz (2013), various changes can occur during BLC, for instance; equipment is replaced and installed into a new location, spaces are used for different purposes and etc. In such a case, if BIM and FM system is continually updated as these changes occur, this will serve as an accurate record of current condition. Hence, FM personnel do not require to look up on drawings or other documentation or break through walls or roof to specify the actual condition. Accordingly, if FM personnel is trained for maintaining the system as the conditions change, far better planning information is going to be available and through the information a better decision can be made. As a result, the cost of renovation is going to be decreased by reducing the uncertainty when contractors bidding on projects. In this way, BIM & FM integration can offer benefits during the entire LC of the facility (Teicholz, 2013).

According to the author, a significant cost benefits results from BIM & FM integration, namely; (1) workforce efficiency is getting better as soon as better information is available when it is needed in office or field, instead of requiring FM personnel to spend time looking up information on drawings, equipment documentation and other particular type of records. (2) cost of utilities is also reduced due to better maintenance data that support better preventive planning and procedure for maintenance (e.g. if mechanical equipment is properly maintained, the equipment in turns will function much more efficiently). (3) BIM FM integration can also reduce in equipment failures and etc. (Teicholz, 2013).

On the other hand, Talebi (2014) mentions some challenges when adopting BIM. In the report it is mentioned that BIM adoption can create new business processes, and implementing them into the processes will face the firms to new challenges. The present challenge would be that how these companies would be able to handle these vague changed processes. Additionally, because of an immature level of the users for the new process, it is difficult for the firm /users to predict the consequences of BIM implementation. In addition, there are also costs associated with use of BIM, for example; a cost which associated with the use BIM-based software, in order to enable the project team/users to implement and adopt the technology to the processes they should have enough training. Another cost incurred by BIM implementation, not using BIM-based software in-house, hence general contractors need to outsource the entire model, which is costly and time consuming. These related costs in implementing BIM are considered as overhead cost and “can be potentially the difference between being awarded a contract or losing it (Talebi, 2014). In contrast, Terreno et al (2015) is very much optimistic about BIM and FM integration emphasising that BIM FM integration offer huge potential for cost saving and improved processes (Terreno et al., 2015).

On the report of Teicholz (2013) it is mentioned that FM staff continually encounters challenges to improve and standardize the information they have at their disposal in order to meet their daily operations. Unlike AEC professionals, FM individuals are not trained in reading drawings or are unable to retrieve relevant data from the as-built documentation. The author further cites that BIM software are complex which need advanced user skills in order to master the application. Consequently, FM might be challenged to keep adequately skilled talents in-house. Apart from utilization of BIM in FM, the major challenge will be automation of data update in BIM model and its integration with FM. Such as, how BIM and FM integration be automated and easily managed (Teicholz 2013).

Considering the significant use of BIM in FM, it is further argued if a 3D geometry is combined with accurate data, instructions and other individual records needed for further BLC, in turn, this will lead employees to having access to such information anytime and anywhere they require. In this way, workforce efficiency will become better and a better decision can be made when performing O&M.

Chapter 3 Methodology

In this report we followed qualitative research approach. According to Hammersley (2013), many definitions have been provided for qualitative research, some are mentioned below:

Qualitative research is a research strategy that usually emphasizes words rather than quantification in the collection and analysis of data. (Bryman & Bell, 2015)

Qualitative research is an umbrella term for an array of attitudes towards and strategies for conducting inquiry that are aimed at discovering how human beings understand, experience, interpret, and produce the social world. (Sandelowski et al., 2004)

According to Bryman & Bell (2015), Qualitative process followed by 6 main steps such as, general research questions, selecting relevant sites and subjects, collection of relevant data, interpretation of data, conceptual and theoretical framework, writing findings and conclusions. By the basic definition of the qualitative research is an umbrella term for a wide variety of approaches to and methods for the study of natural social life (Saldana et al, 2011), we adopted in simple 3 steps and there is theoretical framework, collection of relevant empirical data through interviews and finally we are writing about our report findings and conclusion based on thorough analysis of theory and empirical data.

A literature reviews the account of the literature relevant to a particular field or topic (Bryman & Nilsson, 2011). So, to write our theoretical framework, we took text from different authors and different sources and then framed our theory around our core subject. The large number of books, articles, academic papers, blogs and other sources of information which are related to our topic are used to frame our theoretical part. In this framework, we have narrowed down theory towards our thesis objectives and specific research questions.

To collect the empirical information on the area of research, we conduct direct interviews with different people who are familiar with the filed. Interviews are likely the most used method qualitative research much due to its flexible nature (Bryman & Nilsson, 2011). Interviews are semi-structured and planned before going to conduct actual interview. Typical interview questions which we asked during interviews presented in Appendix A. We had interviews with four candidates from different organizations, in which two are project managers from refurbishment projects and other two are from BIM consultants providing BIM services for FM. From here on words we refer interviewees with their prefix and the details are follows:

PM-A: Project manager from the refurbishment project

PM-B: Project manager from the refurbishment project

Consultant A: CEO of BIM Consultant Company

Consultant B: Director Business Development of BIM provider for Facilities Company

It is worth mentioning that ethical consideration is important issue in a Qualitative research that need to be addressed. According to Bryman & Bell (2015), there are specific ethical issues which are significant to take into consideration, such as the issues of possible harm to participants, lack of informed consent, whether there is an invasion of privacy but also whether deception is involved. In this study, all the above-mentioned issues were considered. All the participants who involved in this study were well informed about the purpose and the objectives of the study. All the interviewees had given permission for audio-recording of the interviews. In order to protect from possible harm to participant observations, the interviewees are named either Project Manager (PM) – A&B or Consultant - A&B.

To present our empirical data we write a chapter *Findings*, in this chapter we present our empirical data in such a way that on each particular or related question different interviewees answered to the question. In this way we find it easy to analyse the different viewpoints from different actors in industry on a particular topic or particular question. This chapter text is only related to empirical data that we collected from the interviewees, and it is not from theory part.

In the final step, we write chapter *Analysis and Discussion*, which is completely reflective and critical analysis of the core subject area. The report attempts to bridge the theory and empirical data and presented our own reflective views. Through this we try to answer our research questions and finally conclude our thesis.

Chapter 4 Findings

4.1 Required information at refurbishment

According to both the project managers (PM) from refurbishing project at SB-2 building at Chalmers (see Appendix B), cost estimation and scheduling are difficult parts when initiate refurbishment for an existing building without having an adequate data. It takes lot of cost and time to measure actual as built measurements if the data is missing, and it is very much hard and time consuming to remove all the furniture and measure it before starting work. So, they put more stress on the need for BIM information like related updated drawings and 3D model etc., before starting design the refurbishment. In their view, 2D drawings don't have all the adequate information about installations, height of installation channels, electricity and water supply. In such a case, it would be better to have a 3D model before starting work. They shared experience on refurbishment project at SB-2 on working with old documents and drawings. Basically, they recreate these old drawings into DWG files through Revit software for the refurbishment project. And all the new installations designed by an architecture in 3D model. Further, the drawings which were only in 2D format, they put all installations back into 2D drawings to make the record and continued with their work. They further express that it could have been a better option having a 3D building model because one could easily work on installations from the architecture 3D design model. Now they have all installations in 3D model like machines and fans at ventilation system, which can be used in facility management.

Project managers mentioned about issues concerning information, like all measurements related to refurbishment were taken from old drawings, not from actual as-built documentation. Later, they planned, designed, scheduled their work based on the available data, yet the data was not actual as-built and not up-to-date. Consequently, in the middle of the refurbishment, they realized that one particular room was smaller than the actual drawings. This created a huge problem, they said. Because at that stage all procurements were done based on designed installations. They further said that the problem solved but was quite expensive and time consuming because of reworks. In addition, Consultant A mentions that at present in refurbishment projects building lacks information and the drawings are outdated. Hence, one must go to the building site and carry out required measurements for the building to get the required information and rebuild the model into BIM. He concluded by saying, "*once we have a BIM model then next when we are going to make some changes, it would be cost and time efficient*".

4.2 Creating BIM / Laser Scanning

Defining BIM is very difficult task, different actors see different way of BIM definition for example most of contractors and PMs think that BIM is a 3D visualization of buildings and could be useful in clash detection, but both consultants agreed that BIM is basically a digital or graphical representation of building or facility, which can be used in the whole life cycle of building. Consultant A believes that BIM is an information model uses for decisions within different roles of different persons in different phases of BLC. Whereas consultant B mentions the importance of information exists in the BIM model needs to be taken care throughout BLC and in whole BLC perspective. However, all interviewees agree on creating a BIM model for existing buildings is a good option allowing to create an as-built documentation. During and after refurbishment of the buildings, all the updated as-built documentation can be utilized for the FM activities as well as the information is used throughout BLC. They further mention during O&M daily changes happen in order to keep equipment functioning e.g. addition or replacement of (ducts, piping system etc.).

The importance of creating a BIM model in existing buildings explained by consultant B as "*all existing buildings contain a bad condition of as-built drawings or one can say non-exists, even it is claimed that they have CAD files, but if you check the reality, these are all outdated documents and worked on outdated software*". He further adds, there are many approaches and techniques exist to create a BIM model for existing buildings depends on the purpose and scope for which it is created. And different processes and tools are using to create BIM e.g. laser scanning, Matterport 3D scan, etc. All the interviewees mention about laser scanning, which is a widely using tool to create as-built condition. But different users adopt different tools, equipment, processes and software, yet again BIM model depends on which purpose one wants to scan the building.

The company which is represented by consultant B uses 3D laser scanning for old buildings and create BIM models so that can be used when starting refurbishment or renovations. And then they create a quite high LOD (level of development) on this model on each point cloud. The laser scanning with point clouds have exact 3D geometry with only 3mm to 5mm accuracy. He further says that it is a challenge when someone desires to laser scan. To what extent and for what purpose the scanning is used? For instance, if you use colour, it will be more expensive, and takes longer time for the scanner to work. According to him, for renovation purpose one can use a tripod laser scanner where it exactly georeferencing points on the model and can align each point cloud and do registration. Next, the point clouds can be imported into Revit add-on option called "Recap" to view or analyse point clouds or connect with design system.

Whereas the consultant A company uses a trolley-based laser scanner called Navvis, which is mounted on wheels with both laser scanners to capture point clouds and cameras to capture real pictures. Further the company practices through divide BIM into four models, *Program information model (PIM), Design information model (DIM), construction information model (CIM) and facility information model (FIM).* According to him when they speak to facility managers who only needs BIM for the facility purpose the company then provides only FIM model. When it comes to FIM it needs not to be an updated as-built BIM model after construction. It may just scans the facilities as-is and develops a 3D internal navigation model (Navvis) and then adds on information to the model. In such a way, this may be contained the only information required for FM.

The project manager for SB2 also uses laser scanning in their current project. Through this they create a 3D navigation model which uses for facility management. It's said that at the time of refurbishment work the company didn't have any complete BIM model but after finishing the refurbishment work, the whole area is scanned with laser scanning. In addition, it mentioned that laser scanning must be done in 3 stages to get full data available for BIM model; first, laser scanning for structure components like pillar, beams or walls etc., second, laser scanning after installation works and finally for finishes. Which (following 3 stage laser scanning) is not done in the SB2, and they did it only after final work, which is done on a trial bases. According to the PM-A complete laser scanning will be done in other projects which is helpful for facility management.

Consultant A argues that with new generation laser scanner one can achieve data enrich laser scan as good as tripod scanner. The main advantages are that trolley-based laser scanners can do both laser scanning and high definition pictures at a time and they are very quick when compare to tripod scanners. However, Consultant B goes further mentioning about different kinds of laser scanners e.g. Navvis which is also a good tool for presentation purposes, internal navigation, user interface for O&M. User can add tags or objects position on clouds e.g. heating sensors, fire alarm position etc. and connect it with FM system (see Appendix C).

According to PM-A, creating a BIM model for existing buildings is expensive and taking a lot of resources and money into the projects, but they want to create BIM model in more efficient way in future projects. The PM further mentioned about the importance of BIM saying that "*though BIM seems to be an expensive practice but has lot of potential in existing buildings and for FM, so one must find a way to do it in efficient way in terms of cost*". It is further mentioned that the company is working on BIM and building digitalization which is under processes and hasn't yet reached to its full usage, and also do scanning old buildings to provide information for facilities. However, scanning should be cost efficient.

4.3 BIM & FM integration

When it comes to BIM & FM integration, Consultant A gives an easy way to see the value creation of BIM in FM is O&M technical part. For example, if any part is broken which requires improvement or reparation, then maintenance staff just sit at a computer and look for required information about the part without site visit and orders it through internet and goes out to replace it. In this way one can efficiently plan and prepares a lot about his/her work, though this FM can improve efficiency in the workplace. Whereas consultant B mentions that many people ask how much money one can save with BIM. It is difficult to answer, he said. He further mentions that we need to analyse information and processes in FM system and the research is going on some working labs, and the results will come out in future. On the other hand, building industry which stands 40% of total energy consumption, he thinks digitalization in buildings is needed and BIM has the ability to provide tools can be used to save energy consumption in existing buildings. For example, if we have BIM model and we know about information about windows or insulation on outside wall, then it gives an overview of current status of insulation capability and energy consumption and make changes in ventilations and installation. Through BIM model one can simulate different approach rather than rely on one expert opinion.

Consultant A believes that, the present FM systems are too old today and they are not adopting what they really require, and there are a lot of new systems but require a lot of competencies to adopt the new systems. Consultant B also believes that the FM systems that were developed so far, is always one or two steps behind, for example when IFC system exports to other system one must correctly set parameters that could be read into other system. This challenges in both exporting and importing of IFC files. So, solutions he sees or his company is supplying for business is database system, which have plug-ins to all the systems; a bidirectional connection between them.

Consultant B further argues that, at present, it is too much focus on which brand of CAD/BIM tools (e.g. AutoCAD, Revit, Tekla etc.), is the best for different stakeholders and that Open BIM or IFC is the "holy grail". According to him, it is more important how the building industry can achieve better use and benefits from the information connected to the BIM model independent of which design tools are used or how well the IFC file is defined (export/import). From a building lifecycle management (BLM) perspective, it is important to use a descriptive database from early stages when the requirements are defined, and later it is connected to the model and gradually populates with the information that is needed throughout BLC. Even if the design and construction phases of a building lifetime are capital intensive, it is the O&M phase that needs a lot more attention, thus better quality information and easier access to them can be updated in a cost effective way.

The company which represented by consultant B practicing FM system, they store geometry in a database, and they use a 3D viewer application that can visualize 3D model independent of who and which system one uses in the design phase. That means the database populates throughout the BLC adding on more information. He adds that when building is used for its operation and having a FM administrative system being connected to the database, then the database can be updated throughout BLC e.g. "change in flooring", etc., he further says "*when doing renovation, within 5 years then you have all the information about the types of flooring in the database etc*.". But the challenge he sees is to make changes into geometry e.g. remove/add a wall etc. then one should go back again to the design model and change geometrics information and update the database. But all other data which is not a geometry data can be directly modified using web server or some kind of communication between FM system and the database. Following "you *have a database, gradually populated throughout the BLC"* he says. It is kind of future development of BIMeye database (BIMeye is an app-based user solution to manage and update building information through cloud-based database for different purposes, e.g. door/window manager or asset manager), and the database is available throughout BLC. He believes that BIM with asset database is necessary and required to be able to have efficient organization and actual cost saving. And industry is agreeing on asset database which is an important matter and will definitely be able to bring a broad usage in the building industry, therefore, there is a need to have an open interface system, where one can connect with other systems.

The company represented by PM-A at SB2 also practicing FM system by storing all the relevant information to FM for new buildings project stored into a particular new database. So, basically, they gather all the information from main contractor or supplier and then records it into a database after handing over the project. For example, if they need any information about carpet, they don't need to contact main contractor, instead they contact direct to supplier. It will helpful in future if any material is hazardous or dangerous, then it will become easy to identify from FM database and replace it with new material, and also helpful to compare the different materials. On the other hand, if there is too much information in the database, it is then hard to get the right information for performing operations in buildings. And their main aim is to place environmental database (like byggvarubedömningen) with BIM model.

Further, company which is represented by consultant A practicing FIM model which is based on internal navigation model called Navvis. According to him, Navvis is very fast and very user friendly if one analyses the problem in FM and to keep updating the information about buildings. He exemplified his point further saying that, if this is seen on a large scale, for instance, a company with a huge built-up area e.g. around 3 million sq. m without having BIM model or doesn't even have complete drawings. In order to create BIM, one should go into BIM of 3 million sq. m for whole model which is rather too expensive and difficult to access BIM model. And he suggests a solution saying that, "*we found mapping like satellite google maps, so one has both satellite 3D mode and google map mode which include the information and work environment*". Thus, they came up with idea of Google map for FM, e.g. once maps are created then information can easily be added, as a result a model with a required information will be built which is needed by every FM or owners.

The consultant A mentions pooling of information in FM is going to be future for FM. To accomplish this he further says that "we *have all the appropriate technology available to do pool of information, but only a challenge is about its scale, meaning how large it is to keeps it as-is"*. Additionally, what missing today is the link between FM and manufacturers, because manufacturers know what exactly is in their products and upgrades in that product? So, we need a stakeholder; one stakeholder and one database is needed e.g. the supplier of the products information everywhere. Therefore, the company is working today with "BIMobject". And he explains about BIMobject database, which is one and large database for all manufacturers around millions of products in one database. So, if we have linked FM database of individual companies with the BIMobject database then the information can be managed efficiently, no need to update product data manually on FM database. So, this may act as a centre of information for all products from different manufactures. So, it may easy to compare between products in terms of quality, efficiency, price etc. between products.

4.4 Information handling

According to consultant B, in the BIM where the "I" (information) is the most important part. Important thing could be what kind of information one have in the model that needs to be taken care throughout BLC. If someone gets work order in O&M such as changing lamps, so one requires the right information about the lamps and its source. In best case he can bring with him all the required equipment and material instead of going to check out, finds out what type of lamp it is, order it and change it. He further describes that if there is enough information in the beginning, then we can save time and money. Furthermore, in regard to information handling, artificial intelligence (AI) can play a big role. For example, if we know the expiration date of lamps in a building through its linked information in the model, we can then easily predict when to change the lamps before they are expired. Through this a working process is maintained in smart way, and you can save time and money. He further emphasizes on the importance of information, saying that the necessity is have the correct information with right source. So, one gets less problems because one knows what is going to be happen.

Consulting A also believes that information is the most important thing and should come from the right source into BIM model. He further clarifies it in an example saying that the present process for the air ventilation system in buildings is that the designer or HVAC engineer doesn't know about end product, only he knows about demand of product, in the next phase the main contractor may buy any product to reach the demand. So definitely main contractor goes for cheapest one, and often the cheapest one is not a good product for FM. And also, the designer uploads the information have taken it from contractor and then uploads it into BIM model. So, anything wrong with product at FM phase or if any information is needed for facility management through BIM, the available information is not adequate or not accurate because the data is lost during flow of information from manufacturer to supplier to contractor to designer and then to FM. So according to him, information of any product into BIM model should directly linked from manufacturer. Besides, it is very important to pass information from right source directly to the end users. As regards the information required for efficient facilities, FM must get information from everyone e.g. designer should provide information about the demand etc., contractor must provide which product is installed and its details and manufacturer must provide all information (e.g. warranty, dimensions and etc.) about product to the FM. Often the above-mentioned information is not accessible for the FM staff in order to be able to carry out building work more efficiently. Furthermore, it is also important to find right materials for buildings, for example any product which is not suitable for FM phase e.g. any floor which is hazardous to health like laminated flooring might causing cancer, then the FM able to contact with manufacture and replace it with different product. He further speaks about the importance of building documentation that can efficiently be retrieve throughout BLC, accordingly FM can make a better decision on facilities, as he says, "i*f we have well-documented information about different products used in buildings, then we can easily manage to make processes more efficiently, as a result one can maximize cost saving e.g. energy saving etc*. *If you make efficient facilities today, you maybe not be making money today but in future with lot of data from BIM model you can obviously make it, if we see this in a long-term perspective"*.

4.5 Challenges to update BIM "as-is"

According to consultant A the problem with FM is to keep updating the BIM model; it is to have an as-built model but very difficult to keep model as-is. For efficient FM the firm needs to change their processes and raising competence. Following, in building construction lot of stakeholders are involved and take decision very late. As a consequence, the profit will be very low with these late processes. He thinks, it would be good to know about what type of material and machines etc. going to fit in the building at very early stages of building planning. There are lot of components to be changed and sometimes laws and regulations comes in.

In consultant B view, it is important to have a database throughout BLC and every stakeholder who uses the database should be able to update the data correctly. He further says, during FM stage of building one should also update the data independent of which system is used, so keep updating the data will absolutely result in an easy access to the database. "*If you can't access the database easily by human behaviour, you just can't update the data. So, human behaviour, right system and correct information in the model are playing key role"*, he says. He further talks about unbreakable information chain which he argues that it requires both systems support and organization behaviour to keep it up-to-date. He thinks that technique/system is about to ready now but the challenge he sees is that it is up to the organizations to adopt the system. Following, it would be lot of improvement coming on to the FM system. He concludes that "*companies must have budget to keep update their data, otherwise the model getting outdated. So, you have invested huge amount to create model and if you don't maintain it then it becomes useless. So, you must have one cost from the budget to create a model and another cost to keep update the model"*.

4.6 Future of BIM in FM in existing buildings

According to BIM consultant A, BIM at present in Sweden construction industry prospective, four years ago there was a low level of competences in the market and BIM consultants were really struggled to get jobs on BIM. But today large projects in Stockholm, Gothenburg and Malmö have raised a lot of competences and the large construction projects in 3 cities are working with BIM. They are working a lot with BIM in design and construction phases, and just started from last year working on BIM in facilities. Industry is moving fast, he thinks within 5 years large real estate may use BIM in all their facilities and from last two years there is too much talk about digitalization in buildings. Additionally, in construction market things are changing now and everyone is looking for ideal opportunities, not only delivering house or facilities, but is seen as a service just like other industries not only delivering a product but also delivering a service to that product. So, there is a large scope for real estate owners if this is moved from just maintenance facilities towards delivering services. He further says that FIM is key to success for that and also increases the asset value, it exemplifies a car having all service information will definitely have a high value than the car with no available information.

BIM consultant A believes that, those people who won't work with BIM now, they will be out of job within 5 or 10 years. Today it maybe a slow process and costly but there is no other option, somewhere there going be a tipping point where there is much more competences to BIM. For FM, BIM going to be a necessary tool, going from non-digital to digital there is a need for BIM and to go from deliver facilities to deliver services they need BIM. In this regard, we need to add new roles in the company. He adds that in FM system, "*what we are missing today is that we have old systems, which were programmed back in 90s and they just build on old technology. But thing will change rapidly with new technology. In 5 to 10 years, he sees BIM as simple as app on mobile. The BIM system going to be lot better and user friendly like simple app or gaming program*".

In consultant B view BIM in future is an asset database the information in the model is necessary and required for an efficient organization which results in cost savings for the organization. In addition to be able to get broad use of the database it is necessary to have an open interface system that different people can easily access and work on it. He then further mentions that it is difficult to give instant answer to building owner how much we can save money from BIM implementation. It needs to analyse that how do we work today and how does the information today looks like.

Furthermore, BIM may look like a hand device; it may be used by anyone for example students in university etc. and temperature sensors in mobile itself. Google tango, apple apps etc. He thinks the approach is to use 3D laser scanning to capture exact constructed geometry inside and outside and shouldn't be digitized with expensive method with all the details but rather to be used a hand device to add on more information.

However, both PMs who are also BIM users at workplace and see present BIM as a tool using for clash detection in design and construction phases of buildings, but they do believe that real benefits are in FM. In the future BIM has lot of advantages especially in maintenance and facilities phase so that we can use information in a correct way e.g., location of equipment onsite is not located exactly on the drawings and difficult for FM staff to find the equipment onsite. Also to match onsite equipment and drawings it requires people to rework which cost and time consuming. They further say, as long as we do BIM efficiently in terms of cost will definitely provide good outcomes. In the meantime we should beware of the technology itself, shouldn't come too expensive or too advance so that we won't be able to use it in future but rather it has to be simple. Moreover, BIM can be very much useful in future for whole lifecycle of building e.g. if any material is hazardous or dangerous at time of demolition or later stage.

Chapter 5 Analysis and Discussions

The findings from interviews show that BIM is a digital representation of buildings or facilities which can be utilized in whole lifecycle of buildings, this can also be found in detail under section 2.4.1. BIM is a shared digital representation of a built object to facilitate design, construction and operation processes to form a reliable basis for decisions, (ISO, 2016). Where "I" in the BIM is a very important aspect of the model representing that which information is required to be included in the model and that needs to be taken care throughout BLC. From BIM points of view when it comes to FM in existing buildings, adequate information is key success factor for efficient FM activities. It is worth mentioning that throughout the lifecycle of facility the largest amount of expenses happens during the operation phase approximately 60% of the total cost, whereas less than 15% cost accounts for the total cost occurs during design and construction (Teicholz, 2013).

In existing buildings BIM implementation may faces some challenge e.g. inadequate data which often lacks for existing buildings will also challenge the BIM. On the other hand, inadequate data or incomplete building information results in an ineffective project management, time loss or cost increase in maintenance. Nevertheless, recent technologies made it possible to overcome such challenges and provide better opportunities for efficient FM. In order to have an efficient FM practices for existing buildings the following sections the important aspects of the BIM & FM for existing buildings is discussed.

5.1 Creating BIM in existing buildings

To analyse, creating a new BIM depends upon its purpose and what information do you want within a model. It might be a just 3D model for refurbishment work or data enrich 3D model to work in FM or just for navigation purpose in O&M etc. Through both literatures and empirical evidences, the 3D model is necessary future building refurbishment work for example ventilations, piping, and all installations are designed in 3D model and later on presented to clients. If you have a 3D model then you can design and plan well for future refurbishment work. So, any adequate available BIM information in old buildings create a value in terms of cost and time, not only in refurbishment or O&M, but also throughout BLC.

As we discussed in theory that there are many tools available to create a 3D model (for more details see section 2.4.3). From both literatures and findings, one can say laser scanning and point cloud technique is widely accepted and practical technique to get as-built or as-is conditions of a building. It capture building's exact size and shape in a very quick time and able to store point cloud information into BIM objects. At present new generation tools available like Navvis which can generate point cloud data through laser scanning in real time and high definition photos together at a time. Which are very useful for presentation or navigation purposes and one can easily link with other systems such as FM database etc., as we mentioned earlier. However, the problem which still remains for the creation of an efficient BIM is the automatic generation of geometric 3D models in authoring tools from in-situ data. That means, at present all technologies and tools using to create a 3D model in existing buildings is semi-automated processes. Furthermore, data interoperability between BIM tools/techniques shouldn't be a complicated process for the purpose of creating BIM model (e.g. conducting laser scanning requires knowledgeable operators when creating BIM model), rather it should be an easy process, simple and cost efficient.

5.2 As-built documentation

Often the as-built documentation is not up-to-date which is difficult to search information on current facilities (e.g. Piping, ducts, etc.) as we also mentioned in section 2.1 theory part BIM data for many existing buildings is lacking for FM practice. As a consequence, inadequate data resulting in an ineffective project management which is both time and cost consuming. Additionally, interviewees agreed upon if the required data is missing for any existing buildings or facilities, it is then time and cost consuming when initiating refurbishment.

When it comes to Operations phase it seems to be the costly phase of building lifecycle as mentioned in section 2.2, and is also confirmed by all interviewees. Usually, during O&M work daily changes might happens in order to keep equipment functioning e.g. addition or replacement of HVAC system (pipe, ducts, etc.). After having some changes into the equipment onsite, the as-built document is still not updated. If the document is not updated in a proper way where all necessary information is required for further facility, this in turn may place a barrier for FM staff for further O&M work. Therefore it is difficult for FM staff to provide accurate information on equipment which is not updated on time of O&M. Accordingly, FM staff can then only provide equipment's detail as per their experience or guesswork. As a result the organization may not have an efficient FM processes and be only dependent on the knowledge of experienced staff who worked for facility operation over the years (for more details see section 2.3.1). If there is no updated as-built documentation which possibly may not match exactly as per installed equipment. Furthermore, the documentation is rarely used or synchronized with a client's facilities management system. So with better BIM utilization throughout facilities, there is an opportunity to link the FM related information with building model. When BIM is implemented to the process, it offer an opportunity to record accurate as-built information. Accordingly this helped to manage and maintain the facilities in an efficient way and increase BLC.

Additionally, location of equipment (e.g. pipes, ducts, etc.) on construction drawings are misplaced or even not existed onsite, which makes it difficult for FM staff to locate and navigate onsite equipment when performing operational work or do other maintenance activities. There are many reasons that the drawings have not been kept up-to-date; for instance, the drawings during construction phase are not updated due to some changes occurred onsite activities, or during life cycle of building lot of changes happen when performing operational or maintenance activities. In order the drawings to be matched to the current as-built existing model, needs lots of rework which is time and money consuming. Furthermore, if the process of drawings continues without being updated for the whole life cycle of a building, will result in an inefficient management for the building which is cost and time consuming process for every time the drawings are updated. To avoid rework on projects' documentation, utilization of BIM can considerably be helpful to keep the projects' documentation up-to-date for the FM and as well as whole BLC. As mentioned in section 2.5.1, the ability to support FM is considered to be an important value-added feature for the BIM approach. The information which is stored in the database during the project is helpful for later retrieval of facilities. Besides, the database has the ability to be updated throughout the whole BLC and can also identify the information required for maintaining the building facilities. BIM implementation on other hand, suggests providing a reliable facility information database and integrated views across all facility system, through which the facility managers retrieve and analyse information about the entire system.

Additionally, BIM has the ability to provide 3D spatial information about buildings and their facilities, and such facilities should continuously maintain during the whole BLC, e.g. ducts, pipes, and other facilities in buildings. 3D BIM has the ability to support visualization and spatial analysis of different maintenance occurs in FM. Through 3D visualization in BIM model one can easily see shape, size and location of the different components in BIM model, this makes it easier for the FM staff searching for the relevant components when performing O&P onsite and to take decision quickly. For example, if someone gets work order in O&M like changing the lamps, one requires right information about lamps and its source. In best case he can bring with him all the required equipment and material instead of going to check out, finds out what type of lamp it is, order it and change it. He further describes that if there is enough information in the beginning, then we can save time and money. Furthermore, in regard to information handling, artificial intelligence (AI) can play a big role. For example, if we know the expiration date of lamps in a building through its linked information in the model, we can then easily predict when to change the lamps before they are expired. Through this, a working process is maintained in smart way. The necessity is having the correct information with right source. So, one gets less problems because one knows what is going to be happen. On the other hand, such situation without BIM usage might delay the FM processes which is cost and time consuming.

In order to perform efficient maintenance, FM staff must regularly locate building components such as (equipment, materials and finishes) and its corresponding information for quick problem detection and resolution. As well as, locating the equipment becomes more critical during an emergency. Or when newly FM personnel or an outsourced FM team takes charge of responsibility for the facility, or without notifying the FM staff in charge the equipment has been changed or removed. As a result, BIM technology in general provides opportunities for FM staff to control and facilitate their daily work. For instance, BIM combined with navigation capabilities can navigate the FM staff to the desired component, just like global positioning system (GPS) connected to maps in outdoor environment. Similarly, if FM staff is provided with a mobile or other digital device that support better navigation tools that facilitate FM activities, will better reduce FM staff dependency on the office staff and/or paper-based drawings (even the drawings are not updated during the BLC). Thus, the FM staff will quickly access to their daily work. Thus, having right information when performing maintenance for facilities, equipment failures will be considerably reduced that cause emergency repairs.

As-built documentation can possibly lack accurate dimensions – the as-built model is not always match to the drawings as provided by architects during design. Taking this into account, during the construction of the buildings some unexpected changes might be happened due to different factors. For instance, width / length of Walls might differ from the design drawings which was provided by architects, width/height of door for some reason might have changed onsite and still not updated per as-built drawings.

Most existing O&M processes do not automatically pre-assign require maintenance for equipment because the FM staff do not have proper schedule for facility work. Warranty and other related information on equipment is not available in order to perform FM work efficiently. And maintenance can only be done on daily/monthly bases and not to be done according to the equipment's actual need. Additionally, often repairs done by FM staff without knowing if there is need or not, because status on repair is unknown to the FM staff in order to see the previous record for O&M work. As mentioned in theory, a linkage from BIM to FM database can help to find and diagnose building equipment with attached relevant information (e.g. product warranty information and maintenance history) which could be automatically connected with the located equipment and sent the information to the onsite staff. Accordingly, FM staff will get the right information at the right place. And based on the information do they have at hand will reach to the right decision.

So, with the BIM utilization there is opportunity to automatically show which component in building should be repair (because of different reason e.g. expiration date might have finished, or some equipment need proper maintenance). When reparation process is done for the equipment it is then recorded into the database with all necessary information which is required for next O&M work. Thus, the process become very efficient and with all required information at hand the FM staff can easily make a decision.

5.3 BIM & FM integration

Through both literature and empirical evidence, BIM & FM integration when done correctly, can provide very significant owner benefits (for more details see section 2.3.5). These benefits come when collection of data is saved over the design and construction processes rather than waiting until the completion of the building. Also, the smart usage of a digital database of building information allows the FM managers and staff to make better and faster maintenance decision and provide higher quality performance. For instance, if any part is broken which requires improvement or reparation, then maintenance staff just sit at a computer and look for required information about the part without site visit and orders it through internet and goes out to replace it. In this way one can efficiently plan and prepares a lot about his/her work, though this FM can perform more efficient. And the same database with stored building information can also support more informed use of the building and its modification over its life. Also, workforce efficiency is getting better as soon as better information is available when this require in the office or field, instead of requiring FM personnel to spend time looking up information on drawings, equipment documentation or other records. Cost of utilities are also reduced due to better maintenance data that support better preventive planning and procedure for maintenance (e.g. if mechanical equipment is properly maintained, the equipment in turns will function much more efficiently). BIM FM integration can also reduce in equipment failures because up-to-date information on equipment leads to better maintenance.

On the other hand, BIM and digitalization has the potential to benefit energy analysis. Through energy analysis, different energy models will be compared to each other and the most efficient will be chosen. This will result in energy saving for existing buildings. Many literatures written on the topic energy-saving for buildings and discovered that building is the largest global consumer of the energy; buildings accounts for almost 40% of the total global energy consumption and most of the energy used by any building is consumed during the operational stage of the BLC (for more details see section 2.5.1). So, by utilizing BIM as a data source for energy analysis, the data input will be more efficient and the existing data more reusable for the BLC.

Additionally, various changes can occur during BLC, for instance; equipment is replaced and installed into a new location, spaces are used for different purposes and etc. If BIM and FM system are continually updated as these changes occur, this will serve as an accurate record of current condition. So, FM staff do not require to look up on drawings or other documentation or break through wall or roof to specify the actual condition. Therefore, if FM staff are trained for maintaining the system as the condition changes, far better planning information is going to be available and through the information a better decision can be made. The cost of renovation is going to be decreased by reducing the uncertainty when contractors bidding on projects. Accordingly, BIM & FM integration can offer benefits during the entire LC of the facility.

BIM & FM integration requires interoperability of system so that the data can be communicated and flowing from upstream system to downstream use. In the literature different way of achieving flow of data and their integration between BIM & FM are described (e.g. spreadsheet data entered to CMMS, using COBie standards, etc.). An effective way is the directly integration of FM system with BIM modelling, where 3D graphics data is updated in BIM whereas FM data is entered into COBie and/or directly into the FM system. Another option is to directly integrate BIM with FM systems supported by cloud-based servers and accessed using a browser.

From the empirical evidence, it is argued that the existing FM system is inefficient and does not adopt what it really requires. When it comes to integration between systems, for instance, when exporting IFC to another system, one should set the parameters correctly that should be read correctly. So, this challenges in both exporting and importing the IFC files. Another challenge for FM practicing BIM is the automatic generation of geometry.

As mentioned earlier cloud-based server is an efficient way of BIM & FM integration as compared to other methods (for more details see section 2.5.3), in which both geometry and non-geometry data is stored in the web-server /database. The database that populates throughout the BLC adds on more information and can be updated with new information. But the challenge nowadays for FM staff with the database/web-server is, that the geometric data in the database cannot be updated automatically in the database. One should change the geometric data from design model and then update the database. But all other data which non-geometric data can be changed directly using web-services or some kind of communication between FM system and the database.

A solution to the above-mentioned issue practiced by one of interviewee is BIMeye, which is cloud-based BIM data management solution for managing and handling of BIM data. BIM with the database is necessary or it is required to be able to have an efficient organization and actual cost saving. And industry is agreeing on cloud-based database which is an important matter and will definitely be able to bring a broad usage in the building industry. Therefore, there is a need to have an open interface system, where one can connect with other systems. But the real challenge is at what extent and how big it is, and an alternative view point to the above-mentioned issue described by another interviewee is the missing link between FM and manufacturer. Because manufacturers know what exactly are in their products and to upgrade the product. So, there is need for one stakeholder and need one database e.g. the supplier of information of the products everywhere, it is called BIMobject database. BIMobject database which is one and large database for all manufacturers around millions of products in one database. So, if we have linked FM database of individual companies with this BIMobject database, then information can be managed efficiently, no need to update product data manually on FM database. So, this may act as centre of information for all product from different manufacture. In this regard it is easy to compare between products, in terms of quality, efficiency, price etc. between products.

Moreover, industry is practicing some specific technologies such as point-cloud and 3D scanning have made it possible to adopt and added value to BIM in a FM operations. Another alternative when FM practices BIM into its operation phase is FIM model, (for more details see 4.2 in findings) which is based on internal navigation model called Navvis. Accordingly, Navvis is very fast and very user friendly, if one analyses the problem in FM it keeps the information up-to-date in buildings. If FIM is seen on a large scale, for instance, a company having a huge built-up area e.g. around 3 million sq. m without having BIM model or not even have complete drawings. On this matter in order to create BIM, one should go into BIM of 3 million sq. m for whole model which is rather too expensive and difficult to access BIM model. With this idea Navvis is a better choice, it works like satellite google maps, and the idea utilized for FM is, once a map is created then information can easily be added, and as a result a model with a required information will be built in a very easy and fast way which is needed by every FM or owners.

5.4 Challenges in the implementation of BIM for FM

As mentioned earlier, FM is considerably supported by BIM approach and BIM FM integration which provides very significant owner benefit, yet there are barriers when implementing BIM for FM. BIM adoption creates a new business processes and implementing them into the processes will face the firms to some new challenges. BIM software are complex and require advanced user skills, so FM is challenged for keeping skilled staff in-house. Also cost associated with use of BIM-based software also pose a challenge, both for training the in-house staff or for outsourcing the model.

The major challenge for FM mentioned by literatures and interviewees will be automation of data update in BIM model and its integration with FM, such as how BIM and FM integration be automated and easily managed. It is further argued by an interviewee that human behaviour on the other hand plays an important key role for efficient FM workflow. He further mentions that during FM phase one should instantly update the data/information, therefore, keep updating the data will lead the FM staff to easily get access to the database and carry daily operational works. He further says, "*if you don't access the database easily by human behaviour after some difficulties, you just don't update the data. So, human behaviour, right system and correct information in the model are playing key role*". He further adds that companies must have a budget for keeping the data up-to-date, otherwise, the model itself getting outdated. He further explains that if firms invest a huge amount of money and time to create a model for further use, if the model is not modified and updated to its current state, then it becomes useless. Hence, you must have one cost to create a model and one cost to keep update the model.

5.5 Information handling

Throughout the literature it has been explained that BIM data for many existing buildings is either lacking or is inadequate for FM practices, because the building is no longer updated during the life cycle of building. As a consequence, inadequate data or building information results in ineffective project management, time loss and cost increase in M&O phase. It is argued that the information is the key factor which plays an important role for efficient FM and throughout BLC and more importantly is to collect, and handle the information in a proper way. Also the information that are lacking or even incorrect information in as-is records is regarded a primary reason for the low level of efficiency in FM for existing buildings (for more details see section 2.5).The interviewee goes further regarding the importance of information into BIM and explains, when it comes to BIM and its further usage throughout the BLC, the "I" (information) is the crucial part and what most important is what type of information do you have in the model, this needs to be taken care throughout BLC. Therefore, information plays a key role for BIM implementation in FM.

Furthermore, adequate information make it easier for FM staff to carry out daily operations and maintenance more efficiently. To this purpose, an interviewee gives an example about how available information for buildings equipment can make the process more efficient. He adds, if FM staff gets work order in O&M e.g. changing the lamps, one requires right information about lamps and its source. In best case, he/she can bring with him all required equipment and material instead of going to check out and find out what type of lamp is required, order it and change it. Therefore, if FM staff have enough information in the beginning, one can easily get work done without any delay and through this one can save time and money. The interviewee explains further and points out the important characteristic of BIM model for FM.

As mentioned in theory that over the whole life cycle of buildings the biggest costs come from operation and maintenance which form approximately 60 percent of the total cost. To the same extent, if the information is handled in a proper way, then there would be an opportunity for greater savings during the operation and maintenance stages (more details can be found under section.2.5). The interviewee further mentions that the necessity is to have the correct information with right source. So, one gets less problem because one knows what is going to be happen. When it comes to BIM model and source of information, all interviewee agree that, in both cases, information is the most important thing and should come to the BIM model from the right source. Thus the FM workflow will result more efficiently. The interviewee explains the situation gives an example as follow; "*the current process for the air ventilation system in buildings is, that the designer or HVAC engineer doesn't know about the end product, only he knows about demand of product. In the next phase, the main contractor may buy any product to reach the demand. So, definitely main contractor goes for the cheapest one, and often the cheapest one is not a good product for the FM. Also, the designer uploads the information about product which have taken it from the contractor and upload into BIM. Anything wrong with product at FM phase and required modification or replacement, and/or any information needs for facility management through the BIM, will not respond to their service when performing FM work. The available information is not adequate or not accurate because the data is lost during flow of information from manufacturer to supplier to contractor to designer and then to FM*". Accordingly, the information of any product into BIM model should be directly linked from the manufacturer. He further says, importantly, the information should pass from the right source directly to end users. Therefore, it is highly suggested that the FM staff must get information from everyone e.g. designer gives information about demand etc. contractor must provide which product is installed and their details and manufacturer must provide all information (e.g. warranty, dimensions and etc.) about the product to FM, which many times the information are not accessible for FM staff.

The literature mentioned earlier insists on a database for keeping the information for further BLC. It is argued that the information which is stored in the database during the project is helpful for later retrieval of facilities. Nonetheless, the database also has the ability to be updated and identified the information required for maintaining the building facilities. Also, the lesson learned regarding implementation of BIM suggest providing a reliable facility information database and integrated views across all facility system. Through this facility managers retrieve and analyse information about the entire system. All the interviewees agree upon the need for a database use for storing all the FM related information for further building life cycle. For example, if any material is hazardous or dangerous, then it will become easy to identify from FM database and able to contact the provider and replace with different materials/products, and easily compare the different materials at the same time and make a better decision. The interviewee further concludes saying that, “if we have documented all the information about different products used in buildings, then we can manage to make process more efficiently. As a result, if the information is stored in a way that can easily available for the FM staff during the building life cycle for further O&M work, then the FM work process will better function. Consequently, the cost and time will be considerably reduced. Additionally, the interviewee then comes up to an interesting point of the efficient use of facilities, “If you make facilities efficient today, maybe you won’t make money today but in future with lot of data from BIM model, can save huge amount, if we see in long term perspective”.

5.6 Future of BIM in FM for existing buildings

As mentioned throughout the theory, lots of reviews and research on BIM implementation exist in a large number for new buildings, but since recently it seems to be a research shift from the very early lifecycle of the building stages to maintenance, refurbishment, and deconstruction and finally the end-of-life consideration. Existing buildings which lacks adequate information regards a primary reason for the low level of efficiency in FM for existing buildings. Often the as-built documentation is not up-to-date for existing buildings which is difficult for the FM staff to search information on current facilities, as a result it places a barrier for FM staff for further O&M work. Nevertheless, When BIM is implemented to the process, it offers an opportunity to record accurate as-built data, and accordingly it helps to manage and maintain the facilities in an efficient way and increase BLC. Also, BIM have the ability to collect, share and manage information through the whole BLC, in this regards BIM has the potential to deliver significant benefits to the facilities management industry. Furthermore, beside 3D spatial information about buildings and their facilities, BIM have the ability to provide a database with stored information during the project which can be used for later retrieval of facilities. Also, the smart usage of a digital database of building information will let the FM managers and staff to make a better and faster maintenance decision and provide higher quality performance. With the available technologies such as laser scanning, photo scanning and point-cloud we can gather information quickly and transform information into a BIM model. Laser scanning and point-cloud surveying techniques which can produce point-cloud data for existing buildings the cloud data can be linked to BIM objects that can be used for designing, renovation or retrofit work (for more details see section 2.4.3).

BIM technology in general provides opportunities for their users to control and facilitate their daily work. For instance, BIM combined with navigation capabilities can navigate the FM staff to the desired building component. Clash detection on the other hand is an important feature for BIM & FM practice, this leads user to identify which elements of different models occupy the same space. The theory further point out that BIM & FM integration when done correctly, can provide very significant owner benefits. BIM & FM supported by cloud-based servers will provide opportunity for the FM staff to easily access to the data anytime using a browser. All information which is stored in the central database will be available all the time. The smart usage of a digital database of building information will make it easier to the FM managers and staff to make better and faster maintenance decision. As a result, this will considerably provide higher quality performance. It is worth mentioning that, BIM and digitalization has also the potential to benefit energy analysis and by utilizing BIM as a data source for energy analysis, the data input will be more efficient and the existing data more reusable for the BLC, this in turn will result in saving energy into existing buildings (for more details see section 2.5.1).

Also, as mentioned by an interviewee, for FM, BIM is going to be necessary tool, going from non-digital to digital there is a need for BIM. He further argues that, in construction market things are changing now and everyone is looking for ideal opportunities, not only delivering house or facilities, but is seen as a service. For instance, other industries not just deliver a product but also deliver a service to that product. So, there is a large scope for real estate owners if this is moved from just maintenance facilities towards delivering services. And to go from deliver facilities to deliver services, there is a need for BIM. Another interviewee goes further in saying that, "*as long as if we do BIM efficiently in terms of cost it provides good outcomes. At the same time, we should beware of the technology itself shouldn't come too expensive or too advance so we can't use it in future. It has to be simple*". BIM consultant we interviewed is much certain about the future of the BIM and says that thing will change rapidly with new technology and in 5 to 10 years BIM will be as simple as app on mobile. Same question answered by another interviewee about the future of the BIM, he responds that, it may be a hand device very simple to use by anyone. The interviewee further mentions about the simplicity of the BIM utilization in the future, saying, the approach is to use 3D laser scanning to get exact constructed geometry for a model but it will not digitize with expensive method with all the details rather to use a hand device to add on more information.

Chapter 6 Conclusion

In the past decades Building Information Modelling (BIM) is increasingly being used during construction sector and BIM is also aimed to support the entire project lifecycle. BIM can be implemented and used at any stage of building, even starting late in a project's lifecycle. This study shows the significant aspects of BIM that benefits FM based on reviewing different academic and other literatures which are related to BIM, information handling and FM.

Existing buildings which mainly lacks adequate information results in ineffective project management, time consumption and cost increase in O&M. With BIM implementation there is a great opportunity for the FM to handle the information in a smart way that will result in updating the information for FM and the whole BLC. Existing buildings can make use of the BIM information concerning building documentation, visualization, facility management etc. Implementation of BIM suggests providing a reliable facility information cloud-based database and integrated views across all facility system, whereby facility managers retrieve and analyse information about the entire system. The result of this study demonstrated that the information should come from a right source into the FM system. The ability to support FM is considered to be an important value-added feature for the BIM approach. And the database should have the ability to be updated and to identify the information required for maintaining the building facilities. In such a case, the smart usage of a digital database of building information allows the FM managers and staff to make better and faster maintenance decision and provide higher quality performance. An efficient integration of BIM and FM provides pre-assigned required maintenance and overall increase in efficiency in daily work of operations and maintenance. Through the integration of BIM and FM can achieve cost and energy saving.

This study has indicated that 3D model which have geometric and non-geometric data is necessary before start refurbishment or changes in facilities, this can also help in the design, planning, scheduling and cost estimating of a refurbishment work at any stage of BLC. Furthermore, creating a new BIM model in existing buildings depends on the availability of pre-existing data and for what purpose the model is created. Based on the purpose one should choose what type of tools, techniques and processes shall adopt. However, laser scanning with point cloud is using widely at present time. Through new generation tools such as Navvis and using FIM model one can create 3D BIM model from point cloud in a very fast and efficient way as-built or as-is conditions of buildings. It gives more reliable data enrich BIM model in very short period of time and it can be easily linked with cloud-based database. However, the tools and technologies which are adopted in the process must be simple and cost efficient. The real challenge will be to keep up-to-date the newly created model to maintain as-is BIM model. It is also important to keep up-to-date the available information as BIM progresses in O&M, considering this, a right system or technology, change in the organization processes and human behaviour in the organization are required. Nevertheless, to keep up-to-date BIM, organizations shall also keep some budget to maintain "as-is" BIM apart from the initial cost to create a BIM model. The key challenge will be fully automation of data update in BIM model and its integration with FM. A case study would be a suitable option to get more results in terms of BIM efficiency in FM, its cost implication, integration of the system etc., however this study suggests further research on the topic.

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Appendix A: Interview Questions

Introduction

1. What is your background and what is your role in the company?
2. Explain about your current project and your daily assignments?
3. How do manage your services in current project?

BIM and FM

4. How do you define BIM? Where did you use BIM in your organization? What about BIM in FM?
5. Could you explain about FM operations now compared with before BIM?
6. What is your opinion on creating a BIM model for existing buildings and its implication on operations and FM?
7. How do we create a new BIM in existing buildings like 3D model, laser scanning, point cloud or image-based model etc.?
8. The BIM which is created during FM stage, is required furthermore data in daily operations? And does it have any effects on maintenance and asset performance?
9. How do you see connecting and linking BIM model with FM computer aided programs? Like CAFM.

Information Handling and "as-is" BIM

10. Since information is key in BIM at any level, could you explain data flow related to FM in your organization?
11. By whom and how they handling this BIM information while creating an information model? Or How your handle information in daily operations?
12. Which information has to be included in BIM objects in order to ensure get more efficiency in FM?
13. How to do think the BIM which is created during FM stage and its data/information keep update? Or maintain "as-is" BIM in future?

Future of BIM in FM

14. Is the present information handling working effectively? Or do you see improvement still to come.
15. How do you see BIM in FM in future as a Facility Manager or service provider for FM?
16. How do you see future of digitization of old buildings?

Appendix B: Refurbishment of SB2

This appendix is about Refurbishment of Samhällsbyggnad 2 (SB2) at Chalmers, which is located at Chalmers Johanneberg campus and address is Sven Hultins Gata 6 in Gothenburg. The existing building SB2 built by Vallgatans Arkitekter AB & Liljewalls AB in 1966. The refurbishment work starts in 2016 to boost the study environment. The extensive rebuilding that began in January 2016 will contribute to more creative and stimulating educational environments with sustainable development in focus (Akademiskahus.se).

Appendix C: Laser scanning

This appendix shows how laser scanning processes are done when making BIM model. The processes for making a BIM model starts from scanning the whole building by laser scanner which generate points cloud. Points cloud then imported to BIM software and followed steps in the software itself until a 3D model is developed and then the 3D model is enriched with required information until a complete BIM model is developed. These processes are shown in Figure I-III.
Indoor navigation viewer is illustrated in Figure IV-V.

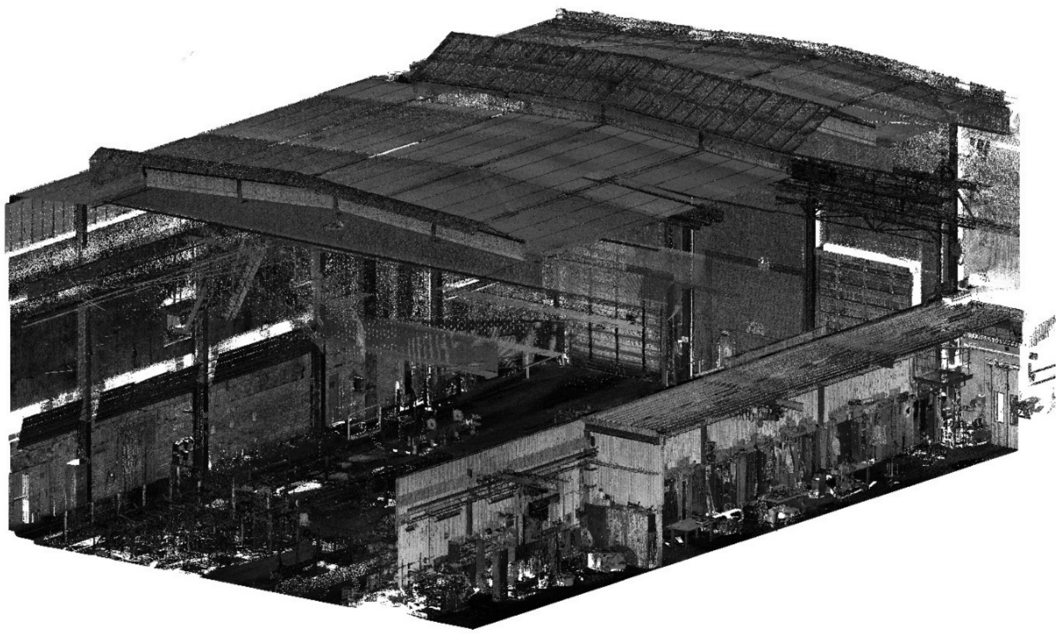

Figure I Punktmoln (Point cloud model) (Zynka BIM, 2018).

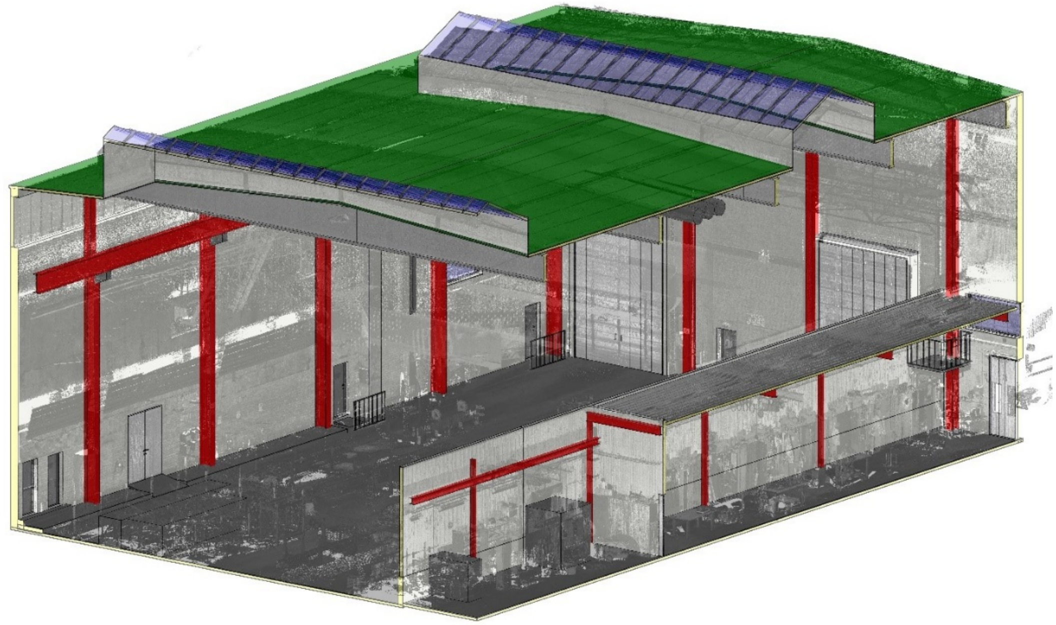

Figure II Punktmoln underliggande BIM-modell (Point cloud model underlying BIM model) (Zynka BIM, 2018).

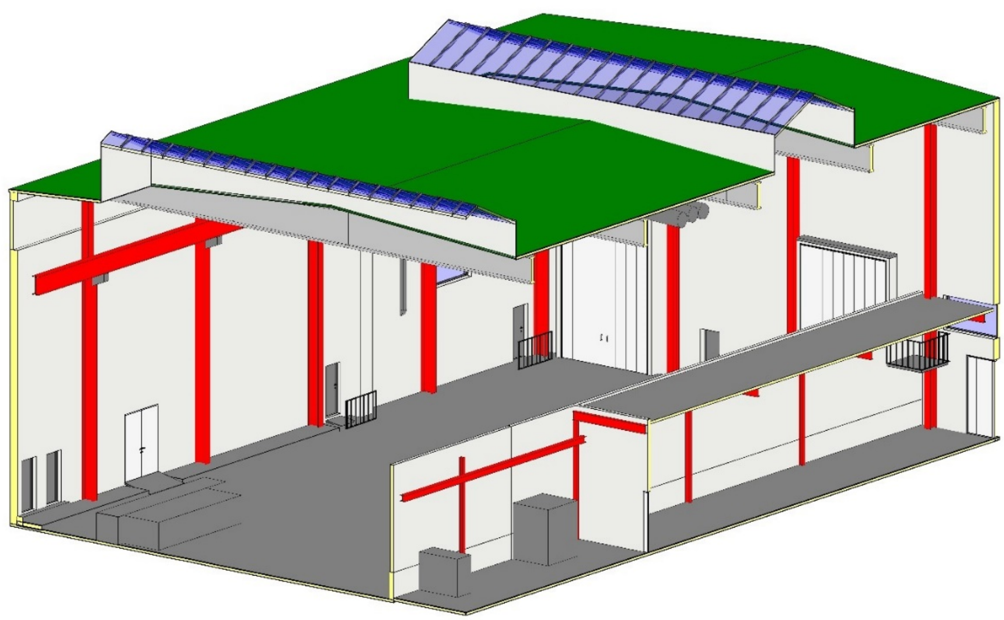

Figure III BIM-model (Zynka BIM, 2018).

Figure IV NavVis indoor viewer i panoramavy varje cirkel går att stå i (NavVis indoor viewer in panoramic view every circle can stand-in) (Zynka BIM, 2018).

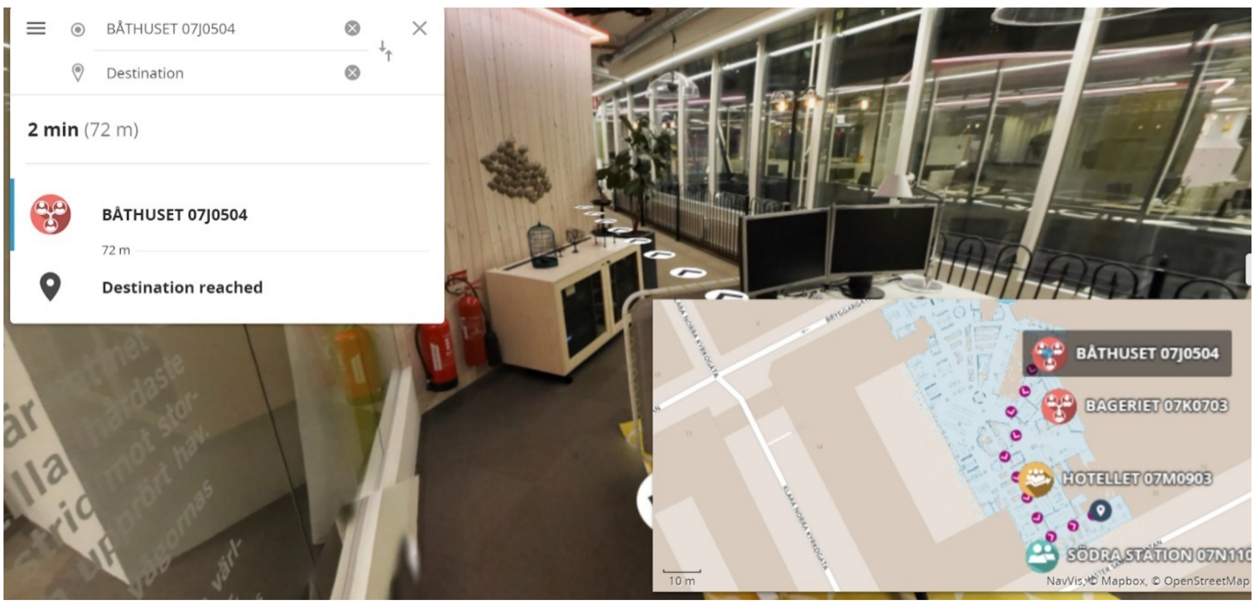

Figure V Inomhus navigering i indoor viewer (Indoor navigation in indoor viewer) (Zynka BIM, 2018).

Figure VI Navvis M6 next generation laser scanner (navvis.com).