CHALMERS
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As-built information
Essential information every facility manager is looking for

Master’s thesis in the Master’s Program Design and Construction Project Management

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CHALMERS UNIVERSITY OF TECHNOLOGY
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ABSTRACT

The AEC industry is largely criticized for poor information recording and sharing and the fragmented use of information. These problematic features are greatly affecting the transfer of information produced in the design and construction phase which should be communicated to the facility management phase. By and large, facility managers heavily rely upon this information to perform their tasks in an efficient way. Furthermore, Building Information Modelling (BIM) which provides an organized structure for information management, currently is mostly used for the modelling purposes in the design of the buildings.

This master thesis shed a light on the current delivery of as-built information and the fundamental deficiencies with the current method and format of delivery. Moreover, the essential information which is supposed to be collected and stored through these models and then ultimately handed over to benefit Facility Management (FM) is benchmarked. Consequently, it is concluded that, BIM as a reliable information management tool could effectively meet the challenges and improve the current information delivery. BIM could make the information retrievable, accessible and audited, but could also evolve the information utilization in more value creative ways such as enabling a loop of information between different actors which could result in knowledge creation.

This master thesis contributes to a method in which FM-BIM specialists could define a structure for an organized and effective information delivery in which all the parameters, objects and information incorporated to those objects are defined to the BIM software which will make the task of locating the information of buildings components more efficient.

Keywords: As-built information, Building Information Modelling, Facility management practices, Facility management required information, BIM in FM

Content

Notations

AEC industry - Architecture, Engineering and Construction
AIM - Asset Information Matrix
BEMS - Building Energy Management Systems
BIM - Building Information Modeling
CAFM - Computer Aided Facilities Management systems
CMMS - Computerized Maintenance Management System
DWG - Drawing (file format)
FM - Facility Management
HVAC - Heating, Ventilation and Air Condition
IFC - Industry Foundation Classes
MEP - Mechanical, Electrical, and Plumbing
PDF - Portable Document Format
RFI - Request for Information

Swedish industry terms
Drift och Underhålls (DU) instruktioner – Operation and maintenance instruction
Relationshandlingar - As-built drawings
Bygghandling – Construction documents, Technical specifications and descriptions for construction
AF-delen (administrativa föreskrifter) – Administrative regulations
Bygglov - building permit

Preface

This master's thesis has been conducted at the Department of Architecture and Civil Engineering at Chalmers University of Technology, Sweden, from January to June 2018. The research is carried out with the support and participation of quite a few persons that should be acknowledged.

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Yashar Gholami
Leo Lindegård

1 INTRODUCTION

1.1 Background and problem description

The AEC industry has been criticized for fragmented use of information, poor information recording and sharing, and lack of a shared understanding amongst all different actors in regard to the information (Bosch-Sijtsema, 2014; Bosch-Sijtsema & Henriksson, 2014; Çıdık et al., 2017). Facility managers are one of the actors who understand the consequent of this poor information communication since to undertake their tasks they are heavily depended on the facility's information generated by preceding actors during design and construction stages (Hardin & McCool, 2015). Therefore, handing over the facility information from the design and construction to the FM phase is essential for the efficient performance of the facility. In the AEC industry, information handover is carried out in the form of delivering as-built information. The aim of this master thesis is to investigate the practice of as-built information delivery which is typically handed over from the production stage to the facility Management stage upon the end of project (Hardin & McCool, 2015; Whyte et al, 2016a) and identify what information can be of value to be integrated in the as-built information from the FM perspective. As-built information, which consists of operational and maintenance data, is intended to provide updated and verified information (Whyte et al, 2016a) on the building elements and they play a vital role in everyday work of the facility managers since their decision making is heavily depended on this information included in the as-built documents (Kassem et al., 2015). Also, it should be noticed that there has been a shortage of research focused on the importance of as-built information delivery which encourage a well-focused attention on the subject.

Moreover, there has been research in seeing value to create a repository of facility data for operation and maintenance phase of the facility by implementing Building Information Modelling (BIM). BIM aim to enable digital integration of information and deliver it as an asset (Whyte et al, 2016a) to improve project delivery and in return benefit maintenance and operation aspects (Kassem et al., 2015). Also, Becerik-Gerber et al. (2012) describe BIM as a coordinated, consistent, and computable building information and knowledge management system to be implemented from design to construction to FM stages of a building's life cycle. Therefore, the benefits of implementing BIM at the FM to enhance the efficiency and efficacy of the FM practices and activities is investigated as well.

1.2 Objectives

The objective of this research is to understand deliveries of as-built information in the current swedish AEC industry in the building market and the challenges and drivers in regard to that. Afterwards, information valuable to the FM stage that is required to be integrated to the as-built information is mapped. Consequently, an investigation on implication and challenges on the BIM-supported approach for as-built information delivery is approached.

1.3 Research questions

- What is the current practice of as-built information delivery in the Swedish AEC industry?
- What is the required information, connected to FM-processes, that should be included in as-built information for these to create value?
- What are the challenges with current methods of delivering as-built information?

- How could BIM-supported information delivery improve the as-built information delivery and meet the challenges in the Swedish AEC industry?

1.4 Limitations

The primary focus in this report is the as-built information and the proposed value this documentation proposes in regard to FM processes. Moreover, only required information and facility management practices in the building market in the Swedish AEC industry are discussed since infrastructure projects have their unique needs.

1.5 Disposition

This thesis starts with a literature review which forms the theoretical framework for this study. Within this section of the thesis various theories, definitions and concepts are gathered in order to make sense of the current position of the industry. This chapter starts with a short introduction attributed to the AEC industry and its relation to information communication. The next subchapters are devoted to facility management, its practices and information required to the FM stage, As-built information, and the role of BIM in deliveries. Subsequently, a theoretical lens is formulated based on ground theories of organizational learning. Organizational learning encompasses four constructs. information acquisition, information distribution, information interpretation and organizational memory. These have been applied in order to analyze the empirical data. Thereafter, the methodology chapter clarifies the applied method for this thesis, describing how the authors have chosen to approach the formulated objective, performed the conducted study and the methods used to obtain the results that will answer the posed questions.

In the following chapter the results are presented, where data has been gathered from actors active in construction, facilities management, and BIM, through interviews. The results are presented in four subchapters consisting of current practice of as-built information delivery, FM required information, as-built information delivery challenges, and BIM-supported as-built information deliveries. In the next chapter, discussion, the theoretical lens is applied to the empirical data analyzing the relation between theory and practice. The final chapter consists of concluding remarks and suggestions for future research.

2 Theoretical framework

In this chapter, theories, definitions and concepts are gathered in four subchapters to cover the area of research questions and purpose of the master thesis. As mentioned in the disposition, firstly, the AEC industry, its particular characteristics, and the essence of information to the industry are presented briefly. Second and third subchapters cover definitions of facility management, the information required to facility management stage, As-built information, and role of BIM in delivering as-built information. And in the last subchapter, ground-theories are introduced to present the importance of the information to an organization and values the organization gain from receiving the information essential to perform their tasks, hence, four constructs of organizational learning are elaborated.

2.1 AEC industry

The architecture, engineering and construction (AEC) industry is firmly known as a project-based industry in which during a finite period of time a variety of stakeholders such as clients, architects, contractors, structural engineers, and heating, ventilation and air condition (HVAC) specialists cooperate with one another to deliver a project to the facility management stage. (Azhar, 2011; Bosch-Sijtsema, 2014; Bosch-Sijtsema & Henriksson, 2014; Shalabi and Turkan, 2017). As a whole, construction projects are characterized as having multiple organizations involved with structural and cultural barriers, being geographically dispersed and with temporal constraints (Bosch-Sijtsema, 2014, Bosch-Sijtsema & Henriksson, 2014). Within this limited period of time, a variety of interactions is carried out between a variety of organization entities, social entities and materials (Çıdık et al., 2017). These numerous interactions lead to vast amount of information which different involved organizations collect and handle within their everyday-basis (Behzadan et al., 2016). Therefore, an efficient and effective management of information is crucial due to observing the different obligations and duties (Behzadan et al., 2016), optimal use of the facility (Becerik-Gerber et al., 2012; Kassem et al., 2015), the quality of decision making during the project or later on during the operation of the facility (Shalabi & Turkan, 2017; Whyte et al., 2016a) and the cost bound to this information (Shalabi & Turkan, 2017; Hardin & McCool, 2015).

However, owing to the barriers and natural features of the industry, communication of the information between different actors and across the lifecycle is inhibited, resulting in fragmented use of information, lack of a shared understanding amongst all different actors, and poor information recording (Bosch-Sijtsema, 2014; Bosch-Sijtsema & Henriksson, 2014; Çıdık et al., 2017). In regard to the challenges, Whyte et al. (2016a) suggest considering information delivery as an asset delivery and utilization of digital-driven data sets, specifically BIM-supported approaches (Whyte et al., 2016b), for information delivery to the facility management stage for maintenance and operation purposes. The informal interaction and rapid exchange of information (Whyte et al., 2016a) between multiple stakeholders including clients, architects, contractors, structural engineers, and facility managers demands a structured approach for collection, analysis, storage, updating, communication and control (Kassem et al., 2015). BIM eliminates the labor and time consuming and error-prone data entry process (Becerik-Gerber et al., 2012), which leads to the elimination of loss of facility information (Shalabi and Turkan, 2017) and provides more flexible and real time responsive decision making (Whyte et al., 2016a).

In order to elaborate the issue, the facility management is discussed in the following subchapter and then the implementation of BIM in information delivery is elaborated in the third subchapter.

2.2 Facility management

By and large, facilities represent considerable investments for their organizations and usually have to accommodate and support a range of activities to support the main purpose that the organization is founded and focused on (Atkins & Brooks, 2015). Within those activities is the organization's core business which explains why the organization is founded at the first place. However, regardless of how well focused the organization is on its core business, it cannot overlook the services which are needed to support the core-business; that is, non-core business (Atkins & Brooks, 2015). Thus, facility management, residing within the non-core business, is perceived as a multi-faceted discipline providing functions and services to enhance and support core business performance of an organization (Atkins & Brooks, 2015; Kassem et al., 2015).

These functions and services, which are supposed to be coordinated effectively, range from financial management, real estate management, space management, building energy management, health, safety, security and environmental management (HSSE), change management, building maintenance management, and domestic services (Atkins & Brooks, 2015; Kassem et al., 2015; Tai & Joseph, 2001). Other publications issued by Jensen (2009), Jensen (2011), Wang et al. (2013) aligned with the International Facility Management Association (Atkins & Brooks, 2015) confirm the mentioned definitions of facility management, holistic nature of the profession (Kassem et al., 2015), and its intent to enhance efficiency and effectivity of the facility's business processes and activities.

However, in order to comprehend the implications and challenges of the discipline, first a clarification in regard to FM practices or in other words what the job of a facility manager entails is elaborated in the following points.

2.2.1 Facility management practices

2.2.1.1 Domestic services

One of the most well-recognized aspects of the FM is managing and planning the cleaning and janitorial services, security and waste (Atkins & Brooks, 2015). These services are the preliminary services which are basic to keep the facility's use.

2.2.1.2 Building maintenance management and repair

As a rule, maintenance activities of the facilities could be synchronized in three sub categories. Preventive, predictive (planned), and corrective (repair) maintenance (Becerik-Gerber et al., 2012; Shalabi & Turkan, 2017). Preventive maintenance could be related to inspection of the operational components to control if they work properly. Predictive or planned maintenance aim to predict the time that equipment failure might occur and collect information and prompt actions to prevent the failure with lower costs compared to preventive maintenance. Nevertheless, whereas the information required for preventive maintenance is usually available from manufacturers, the information for predictive maintenance could be challenging to acquire (Shalabi & Turkan, 2017). Anyhow, both Preventive and predictive maintenance activities are performed while the equipment is still working, to lessen the probability of malfunctioning. Corrective maintenance is mostly regarded to reflection concerning to trouble calls (i.e., a room is too cold, or pipe is leaking) and to replace obsolete items (Becerik-Gerber et al., 2012). As a solid example regarding Building maintenance management is maintenance and repair of Heating, Ventilation, Air Conditioning, and Cooling (HVAC) systems and equipment of the buildings (Shalabi & Turkan, 2017).

2.2.1.3 Monitoring and optimizing the energy performance

Controlling and optimizing the energy performance of the facility could be a vital aspect of facility management. Energy use accounts for approximately 40 percent of the operational cost of the buildings (Hardin & McCool, 2015) and currently from 25 percent to 40 percent of energy consumed by a facility's HVAC system is wasted worldwide (Shalabi & Turkan, 2017). This might be owing to degraded or defective HVAC systems in the buildings (Becerik-Gerber et al., 2012). Therefore, having a system in place to collect and store information, in this case to backup predictive maintenance, to monitor energy performance would be not only cost effective but also environmentally sustainable. (Hardin & McCool, 2015; Shalabi & Turkan, 2017).

2.2.1.4 Checking maintainability

''Maintainability is defined as the ability to achieve optimum performance throughout the lifespan of a facility with a minimum life cycle cost'' (Becerik-Gerber et al., 2012, P. 435). Whereas initial capital cost and design and construction costs are prioritized most by the clients in the AEC projects, it should be noted that 85 percent of the costs (Hardin & McCool, 2015) incurring to a facility across its life cycle comes from the operation and maintenance activities (Shalabi & Turkan, 2017). One of the integral aspects of the facility's delivery process is to minimize the total facility-related cost in FM stage associated with defects arising from design and construction work (Becerik-Gerber et al., 2012). Thus, design stage and facility management stage are interrelated owing to operational aspects of a facility. Operational requirements of a facility need to be taken into consideration when designing a new or refurbishing a facility (Atkins & Brooks, 2015). These considerations might be for instance on space optimization or HVAC system of the buildings. In addition, the principal of constructability is widely considered in the design stage while the principle of operability is not similarly realized (Atkins & Brooks, 2015; Becerik-Gerber et al., 2012). Also, planning the operational and maintenance activities from the earlier stages (Hardin & McCool, 2015) could be beneficial to assess the maintainability of the buildings (Becerik-Gerber et al., 2012). Therefore, using facility's historical data to use the life cycle lessons that are learned from the past and utilize that in the design and construction of new buildings would be beneficial (Becerik-Gerber et al., 2012; Kassem et al., 2015).

2.2.1.5 Space management

Space management aims to optimize the utilization of the spaces in a building. Effectivity in space management is crucial in the sense that facility managers require to predict requirements on different spaces in a facility and manage the related information on the physical asset (Becerik-Gerber et al., 2012).

2.2.1.6 Strategic FM

Jensen (2011) describes another aspect of the facility management including long-term development of the common infrastructure, and development of the facilities and offered services as well as defining objectives and policies for the facility management organization which has been earlier labeled as strategic FM by Tai and Joseph (2001). Efficiency of the personal working for the organization, providing internship and education for them (Becerik-Gerber et al., 2012), and development of use of ICT in the organization could be also categorized in the strategic FM which aim to improve facility management organization (Atkins & Brooks, 2015; Eastman et al. 2011) and in return decreasing the turnover cost at the FM stage to the property owners (Atkins & Brooks, 2015). Connected to the mutual relationship between the facility management and the previous stages and the opportunity to correlation and collaboration to enhance the facility performance, Jensen (2011, P. 81) introduces supply chain management theories which facility management could be applied into the theory as a part of the downstream chain. Supply chain management is defined as “the management of upstream and downstream relationships with supplier and customers to deliver superior customer value at less cost to the supply chain as a whole”. It is also described as ‘’a network of connected and interdependent organizations mutually and cooperatively working together to control, manage and improve the flow of materials and information from suppliers to end-users” (Jensen, 2011, P. 81). Above definitions emphasize the collaboration and interdependent relationship to produce value as an output.

Overall, facility management practices are effective if its activities add value to the core business of an organization and mitigate risks threatening the business model (Atkins & Brooks, 2015). Currently, many companies are missing opportunities to reduce cost and enhance performance because they give limited attention to managing their property assets. One of the key prerequisites of achieving best value is having an informed client. An informed client should possess knowledge on end-users and their needs, service requirements, service targets, and be capable of making informed decisions to enhance the all practices (Atkins & Brooks, 2015). Informed decision making should be based on the accurate and required information (Whyte et al., 2016a).

2.2.2 Valuable information for facility management

The required facility information for the facility management purposes varies based on the property owners and needless to say the different types of the facilities (Hardin & McCool, 2015). Nevertheless, Hardin and McCool (2015), Róka-Madarász et al. (2016), and Shalabi and Turkan (2017) have tried to provide a benchmark on different information needed to perform the facility management activities. To facilitate organizing different information, they could be categorized in eight divisions. The first category could be described as information on the building energy performance and more explicitly HVAC and lighting equipment. The second and third are spatial information on walls, floors and ceilings, and all the quantities, sizes which are known as Geometry and Dimension. The fourth is the used material in the building. The fifth and sixth would be warranties and design life and the seventh is function description of the functional components of the building, spare part lists, and suppliers and manufacturers’ instructions for example requirements of MEP components. The last category would be cleaning costs, building tax, authority fees, and property Insurance known as administrative cost.

The quality of this information is quite critical as accuracy of this information is considerably essential in the informed managerial decision making (Shalabi & Turkan, 2017), prompts action when needed (Róka-Madarász et al., 2016), and improves the efficiency of the facility management processes (Becerik-Gerber et al., 2012). Consequently, there are FM practices which receiving the complete and accurate facility information could enhance their workmanship performance and efficiency. Those FM practices are: Building maintenance management and repair, Energy management, locating building components, space management, checking maintainability, strategic FM and domestic services (Becerik-Gerber et al., 2012; Kassem et al., 2015; Shalabi & Turkan, 2017). Moreover, there is an increasing demand from the end users and tenants asking for more flexible, high quality and sustainable structures (Hardin & McCool, 2015). As a result, providing the tenants with the information on the carbon footprint or environmental certificates on the facility might be another aspect of information delivery.

Overall, ‘’Information is the lifeblood of facility management’’ (Atkins & Brooks, 2015, P. 301). Information empowers the property owners to have control over their facility assets. Information entering the facility management stage has a broad breadth which maintaining the reliability and validity of each piece of it generates obvious and hidden values to the owners (Atkins & Brooks, 2015; Whyte et al., 2016b). Hence, having a system in place with the facility management to collect, analyze, store, update and communicate the information is of the essence (Kassem et al., 2015). Information management starts with recognizing information which is essential for operational and maintenance activities of a facility (Atkins & Brooks, 2015). However, according to Çıdık et al. (2017) and Whyte et al. (2016b), it is a quite challenging task to specify data requirements for the operation and maintenance activities. Also, information which occupants are concerned with is another part of collecting information (Hardin & McCool, 2015). By collecting and managing the information, information asset is delivered alongside the physical asset upon the project close-out (Whyte et al., 2016b). Also, the validity of this information should be confirmed by the client’s inspectors to make sure all requested in the specifications are provided (Whyte et al., 2016b). This enables the facility manager at the start-up of their work with information on the spaces that will be serviced, the services which will be supplied and how to perform those services. Thus, a change to the attitude of seeing information management as a trivial practice to a necessary practice integrated to the organization’s activities and processes is needed (Atkins & Brooks, 2015).

2.3 As-built information

The as-built information could be described as an asset (Whyte et al., 2016a) which provides information on the building’s components and elements (Hardin & McCool, 2015) in the time of building delivery to the facility management phase for the operation and maintenance purposes (Çıdık et al., 2017). The as-built information is expected to show updated, accurate and complete (Hardin & McCool, 2015; Shalabi & Turkan, 2017) set of information on the building’s elements which are operated and maintained by the property owners (Whyte et al., 2016a). In other words, property owners demand the as-built information for efficient and effective (Behzadan et al., 2016), sustainable and safe performance of their facilities (Hardin & McCool, 2015; Whyte et al., 2016a).

This asset carries significant value owing to the fact that comprises indispensable information which activities and decisions of facility managers are heavily relied upon (Aljumaili et al., 2012; Goedert & Meadati, 2008; Shalabi & Turkan, 2017; Whyte et al, 2016a), and good quality of the as-built information contribute to substantial life-cycle savings (Hardin & McCool, 2015). As Hardin and McCool (2015) explains only 15 percent of total facility costs are related to the effort of designers and contractors. In other words, 85 percent of total facility costs are costs incurred after handing over the project to the facility management stage. Moreover, ‘’according to the report published by the U.S. Association of Higher Education Facilities Officers and the National Association of College and University Business Officers, facilities maintenance costs have raised by $5.5 billion since 1988 and are still increasing (Shalabi & Turkan, 2017, P. 04016081-3).’’ As an example, energy use accounts for approximately 40 percent of the operational cost of the buildings (Hardin & McCool, 2015). Arguably, Shalabi and Turkan (2017) claims 30 percent of waste of energy has been reported in the US commercial buildings due to the poorly maintained HVAC systems. Hardin and McCool (2015) argue that on time maintenance can create between 8 and 15 percent operational savings which considering the total cost of energy would be a noticeable figure. These on time maintenance and operational activities need informed decision making. The informed decision making requires to be based on the relevant, reliable and of high quality information (Whyte et al., 2016a). That is why it is concluded that the quality of as-built information is extremely important in facility management decisions (Becerik-Gerber et al., 2012; Behzadan et al., 2016; Hardin & McCool, 2015; Shalabi & Turkan, 2017).

Whyte et al. (2016a) explains some other values of handling the information across life cycle of a facility. Transferring the information across the facility life cycle enables reusing of data and information which leads to mining, combining and interpreting them in value creative ways. One of these value creative ways, as Becerik-Gerber et al. (2012) explain is creating a fully closed loop between design, construction, and FM operations data and use the information and lessons that are learned from the past to use the design and construction of new buildings. According to Bryde et al. (2013) due to the fragmented nature of the construction industry, knowledge which is obtained during and after the completion of the project is mostly not retained to be utilized in the next projects. Therefore, Whyte et al. (2016a) highly emphasize on considering as-built information as a deliverable especially in the complex project. They realize as-built information as an enabler to proactive decision making or real time decision making which result in competitive edge over the organization peers.

As already mentioned, the as-built information consists information on different facility components which are operated and maintained by the owner. As a rule, this information might include as-built drawings, building energy performance, materials and all the used quantities, maintenance schedule, operation planning, design life, warranties, property insurance and etc. (Hardin & McCool, 2015; Whyte et al., 2016a). Nevertheless, it is up to the property owner which upfront the project species to the designers which type of mentioned information should be included in the as-built information in the downstream (Çıdık et al., 2017). All the other types of mentioned information have already been elaborated in the facility management subchapter. Nevertheless, as-built drawings as an integral part of as-built information is explained below. The Oxford university press (2012) has provided a dictionary for construction, surveying and civil engineering which contains definitions on all subjects existing in AEC industry. The dictionary defines as- built drawings as: ‘’Drawings that show how a building has been constructed; the true position of service’’. Hardin and McCool (2015) also explains the definition of as-built drawings and differentiate them with record drawings. Record drawings are those documents going from designers to constructors giving information on how to build a project whereas as-built drawings show how a facility has been in reality built. Through integrating changes occurring during project into the record drawings, as-built drawings or up-to-date plans are generated (Whyte et al., 2016a).

Not surprisingly, it is claimed that there are a few challenges toward providing the valuably accurate and complete as-built information. Delivering as-built information, the path begins with the information collection during the design, continuing integrating information throughout the construction and transferring meaningful information to the property owner to utilize in the facility management stage (Hardin & McCool, 2015). Throughout this path the information should be available, retrievable, and audited to be verified for consistency of the information (Whyte et al., 2016b). However, achieving these features have been remained a challenge (Çıdık et al., 2017) and needs an organized way to prevent overload of information yet create value to the owners (Bryde et al., 2013).

Typically, during the building processes contractors might not be able to follow construction based on the plans or models, because of co-ordinational, buildability or later changes (Hardin & McCool, 2015). As an example, installation of a pipe can differ from what exist in the plan such as plans show a straight pipe while the pipe is bended in reality. However, if these changes are not integrated in the drawings, either plans or models, results in semi accurate as-built information. This ends up to a distrust toward the asset information (Whyte et al., 2016a) and the problem is ignored until somebody gets to an emergency situation having to digging them for example in drawings closets (Hardin & McCool, 2015). Also, in AEC projects a variety of stakeholders are involved often each using large data sets on their own (Behzadan et al., 2016). As a result, creating an integrity between all the document of information could need a structured framework (Whyte et al., 2016a). Moreover, as information transfer in AEC industry relies on formal links, such as contracts (Bosch-Sijtsema & Postma, 2010) procurement of as-built information must be included in the contract (Azhar, 2011; Hardin & McCool, 2015). Also, inspectors should carry out spot checks to make sure the information provided is accurate in the commissioning stage (Azhar, 2011; Hardin & McCool, 2015) and if necessary client could link between the exact as-built information to payments (Hardin & McCool, 2015). Anyhow, the value of complete as-built information needs a reconsideration as its effects and dependence of facility managers on them are extensive.

By and large, in the today's AEC industry, delivering of as-built information is performed in a folder of printed documents, PDFs, and DWG format files. Hardin and McCool (2015) use the term artifacts delivery for this more traditional approach of delivering as-built information. The alternative is implementation of BIM-supported approaches, aiming to use 3D digital data sets and IFC schema to transform project delivery in an efficient way (Behzadan et al., 2016; Kassem et al., 2015). Both manners are discussed in the following subchapters respectively.

2.3.1 Artefacts deliveries

Artifact deliveries is a term used by Hardin and McCool (2015), to describe delivered construction documents holding a few specific features. 2D information display, being static, lack a linkage between different set of documents, showing difficulties to validation, and lacking flexibility to become updated across the life cycle are amongst those predominant features. Traditionally, as-built drawings, request for information (RFI), submittals, change orders and specifications are typical construction documents which contractors hand in to the owners in the file drawers or boxes at the project close out (Hardin & McCool, 2015).

The first problem with this delivery is information existing in the documents is information regarding how to construct the facility while facility managers need specific information on how to operate and maintain the facility. PDFs, as an example of artifacts deliveries, have been perceived as a standard for as-built deliveries for more than a decade. They are accessible and easy to work with for everyone. However, they are not simple for facility managers to interpret the information. Since facility managers have not been involved in the construction stage they do not have the same insight and control over the PDF document as contractors do. Also, much information integrated to PDFs consists of information exchanged between the designers and constructors which has no value for operational purposes and this issue often leads to overload of information. Also, the static feature affects most work of the facility managers. For example, facility managers need to integrate a removed wall after a refurbishment or when a new ventilation equipment is installed to the as-built information to prevent information loss. With the PDFs or printed document including new information to the previous ones is not so feasible (Hardin & McCool, 2015).

All the mentioned shortcoming leads to looking for a framework for update and modify information anytime during and after project delivery or in other words, dynamic information delivery which result in more precise analytical decisions. (Bryde et al., 2013; Whyte et al,2016a).

2.3.2 The building Information Modelling

The organization of the built environment is founded based on interactions between a variety of organization entities, social entities and materials within a limited period of time (Çıdık et al., 2017). This interaction, according to Behzadan et al. (2016), results in creation and collecting a mass of information by the project teams, which demands an organized and structured way (Whyte et al,2016a), to support efficient and effective decision making. ‘’Building Information Modelling (BIM) provides an accurate digital model of a building which simulates the construction project in a virtual environment to present potential issues to involved actors and to meet information needs of all the actors involved in a project from planning, design and construction phases to facility management phase (Azhar, 2011, P. 241)’’. In other words, BIM intend to enable digital integration of information and deliver it as an asset (Whyte et al, 2016a) to improve project delivery and which could in return benefit maintenance and operation aspects (Çıdık et al., 2017). Also, Lee et al. (2015) and Eynon (2016) argue to regard BIM as a coordinated and computable information and knowledge management tool in the whole project life cycle. And more particularly, Becerik-Gerber et al. (2012) describe BIM as a coordinated, consistent, and computable building information and knowledge management system to be implemented from design to construction to FM stages of a building’s life cycle.

As previously lifted up in the introductory subchapter, AEC industry is regarded with difficulties in information record and sharing, poor communication and lack of appropriate collaboration in a project (Bosch-Sijtsema, 2014; Bosch-Sijtsema & Henriksson, 2014). BIM is seen as a potential solution to meet the well-known challenges (Bosch-Sijtsema, 2014; Çıdık et al., 2017; Shalabi & Turkan ,2017). BIM enables information sharing through all stages of the construction project. One aspect of information sharing, which is the essence of this subchapter, is creating and making as-built information accessible to the facility management actors (Lee et al, 2015). The objective is creating a repository of facility information for operation and maintenance activities which is accurate and accessible when needed. (Kassem et al., 2015; Meadati, 2009; Shalabi & Turkan, 2017). Hardin and McCool (2015), also, realize a need for promotion implementing BIM in the facility management operations to life cycle cost savings.

Below studies show that the information which is collected and integrated through the BIM process by the project teams could be proved beneficial to different facility management practices. Here quite a few aspects of different FM practices which could be benefited by implementing BIM are elaborated by Becerik-Gerber et al. (2012), Hardin and McCool (2015), Kassem et al. (2015) and Shalabi and Turkan (2017) which have done qualitative and quantitative studies to investigate BIM benefits at FM stage.

2.3.2.1 Energy management

As already mentioned in the beginning of the subchapter, energy consumption accounts for roughly 40 percent of the operational cost of the facilities (Hardin & McCool, 2015). 30 percent of this amount is estimated as waste (Liu et al., 2012; Shalabi & Turkan, 2017). Hardin and McCool (2015) claim that on time maintenance can contribute to between 8 and 15 percent operational savings yet having a comprehensive information system in place for collecting and managing accurate information for validated decision making and retrieving the information on equipment when needed is essential (Shalabi &Turkan, 2017). To control HVAC and lighting equipment performance and reduce the energy waste, Building Energy Management Systems (BEMS) are developed. BEMS are a collection of microcomputers comprising of sensors and controllers which operate under supervisory control equipment and software to report any equipment failure (Shalabi & Turkan, 2017). Information recorded by the sensors and controllers could be i.e., temperature, CO2, daylight and occupancy levels, zone airflow, equipment failure etc. (Shalabi & Turkan, 2017).

However, currently, this practice is not adequately efficient. Data captured by the (BEMS) has to be communicated to the other facility management systems which due to the interoperability constraint could cause incompatibility and information inaccuracy (Shalabi & Turkan, 2017). Also, in the time of installation of a new equipment or undertaking a repair, the associated information need to be entered manually, which may result in inaccurate and incomplete information (Kelly et al. 2013; Shalabi & Turkan, 2017). Thus, facility managers waste a large portion of their time on nonproductive tasks, such as searching, and validating different pieces of information. BIM, with its data repository capabilities, is sought to enhance current FM practices by overcoming interoperability, visualization, and fragmented data usage and this could enable facility managers to minimize the lead-time of nonproductive activities necessary for maintenance (Shalabi & Turkan, 2017).

2.3.2.2 Locating building components

It has been known that facility managers have to regularly locate building components and dig the information regarding these components in the time of problem detection and resolution (Becerik-Gerber et al., 2012). Conventionally, HVAC systems, electrical and gas lines, and water pipes are located behind the walls, above the ceilings and under the floors which is, needless to say, not easily visible. It is a time consuming and labor-intensive work to locate the equipment based on the blueprints especially when the drawings are not updated or are semi accurate and in the time of emergency or when a new facility manager comes on board this task could be even more complicated (Becerik-Gerber et al., 2012). It could be claimed that implementing 3D BIM as-built models to locate the MEP components in a more efficient way. Facility managers could use BIM functions such as view, search, filter, and highlight the targeted component and related information on it to lower the cost of maintenance by eliminate the on-site speculation (Becerik-Gerber et al., 2012). Recently there has been an efficient way to provide all the building components in the 3D BIM environment and that is laser scanning (Kassem et al., 2015). Laser scanning works like a camera taking 360-degree photos which enable capturing all the building components in the BIM environment with suitable accuracy.

2.3.2.3 Space management

Space management mostly deals with optimizing the physical utilization of the spaces in a facility. To manage the space in a facility efficiently, facility managers require to have access to a representation of different spaces in the facility including its descriptions and boundaries. Building Information Modeling can visualize space attributes which facilitates underutilized spaces identification, space requirements prediction, space analysis, and compare actual with planned space utilization (Becerik-Gerber et al., 2012).

2.3.2.4 Checking maintebility

‘’Maintainability is defined as the ability to achieve optimum performance throughout the lifespan of a facility with a minimum life cycle cost’’ (Becerik-Gerber et al., 2012, P. 435). Whereas initial capital cost and design and construction costs are prioritized most by the clients in the AEC projects, it should be noticed that 85 percent of the costs (Hardin & McCool, 2015) incurring to a facility across its life cycle comes from the operation and maintenance activities (Shalabi & Turkan, 2017). One of the integral aspects of the facility’s delivery process is to minimize the total facility-related cost in FM stage associated with defects arising from design and construction work (Becerik-Gerber et al., 2012). As Atkins and Brooks (2015), Azhar (2011) and Hardin and McCool (2015) argue BIM could contribute to maintainability assessment, similar to constructability assessment, which focus on efficient performance at various stages of a facility’s life cycle. Therefore, integrating FM specialists during design and construction stages regarding their input for their upfront needs is needed to realize BIM benefits (Shalabi & Turkan, 2017). As (Becerik-Gerber et al., 2012, P. 436) explain ‘’the involvement of the FM personnel and the use of historical BIM data across buildings can potentially provide a fully closed loop between design, construction, and FM operations data. Moreover, lessons that are learned from the past and stored in BIM can be used to shape the design and construction of new buildings and foresee and reduce risks’’.

2.3.2.5 Visualization and marketing

BIM’s well-known 3D graphical feature provides an interface integrating material texture, light sources, landscaping, and so forth which enables what-if analysis and assessing construction methods in the time of renovations. As a result, through modelling, construction equipment access for operational activities could be visually controlled. Furthermore, the above features of BIM could be used to create animations of the interior spaces and furniture for the marketing purposes (Becerik-Gerber et al., 2012).

2.3.2.6 Challenges for BIM implementation at FM

In spite of all the mentioned applications and benefits of using BIM for FM purposes, there are challenges and implications regarding using BIM as the information distribution media to the FM stage which are explained below.

- The first challenge is a requirement for a well-established process to update the designed model and integrate the configured information to the model to obtain the as-built information (Kassem et al., 2015).

- The second challenge is the unclear role and responsibility for loading data or updating the model to keep the accuracy of the model (Azhar, 2011; Becerik-Gerber et al., 2012; Kassem et al., 2015). The issue that who will incur the cost of updating the model is also likely which should be settled before the start of the project.

- The third challenge which is quite prone in today’s AEC practices is diversity in BIM and FM software tools which leads to interoperability (Azhar, 2011; Kassem et al., 2015). Another issue arises when subcontractors use another software as the main contractor does. As a result, the contractor should update and integrate different data into the BIM model which is extra cost and work which should be addressed in the contract (Azhar, 2011). Also, another issue is there is already some different databases for facility management operations. Computer Aided Facilities Management systems (CAFM) supports facilities management activities such as planning maintenance, work orders, procurement, space management, capital planning and so forth (Eynon, 2016). Building Energy Management System (BEMS) manage energy usage and lighting systems. (Eynon, 2016; Shalabi & Turkan, 2017). Also, in some cases, facility maintenance data, are stored and managed in a different FM database, called Computerized Maintenance Management System (CMMS). These complex systems provide good quality data for FM, but they lack interoperability and visualization capabilities (Kassem et al., 2015). The other problem is data from (CMMS) is not compatible with BEMS (Shalabi & Turkan, 2017). According to Shalabi and Turkan (2017) Insufficient interoperability between these systems result in a $15.8 billion total added cost in the construction industry. Arguably, Building Information Modelling is regarded as an effective solution to settle interoperability problems (Lee et al., 2015) with Providing a schema that integrates FM information systems data in a three-dimensional (3D) IFC environment (Kassem et al., 2015). The industry foundation classes (IFC) are a data exchange schema standard for BIM, containing data on the building components and presenting connections between those components, was developed to resolve interoperability issue among various software used in the AEC industry (BuildingSMART, 2013; Shalabi & Turkan, 2017).

- For the fourth challenge, it is argued that (CAFM) and (CMMS) could store the required data yet they lack a user-friendly interface. This issue impacts the quality of maintenance data since they have difficulties to communicate the output data and support the user needs which leads to data quality issues (Aljumaili et al., 2012; Shalabi & Turkan, 2017) and, therefore, Shalabi and Turkan (2017) state that (CAFM) and (CMMS) are not designed for the facility managers' specific needs (Kumar et al. 2014; Shalabi & Turkan, 2017).

- One possible problem could be toward the ownership of the model. Since the client pays for the creating the model, they might realize themselves eligible to own the model yet other actors such as designers or contractors might enclose information which belongs to their own firm exclusively. Consequently, the legal boundaries appear and Azhar (2011) argues there is a possible solution to solve the problem. This issue should be clarified and resolved early in the contract to avoid the further copyright issues.

- And last but not least is existence of a few organizational problems. One obvious challenge is the requirement for new investments since organizations need to invest in infrastructure, training, and buying new software while there is a lack of real world cases to prove a positive return of investment (Kassem et al., 2015; Shalabi & Turkan, 2017). To point out to other organizational challenges (Becerik-Gerber et al., 2012) mention the cultural barriers toward adopting new technology and organizational resistance toward adapting to fundamental changes.

To conclude, BIM adoption in FM, is still in its early stages (Kelly et al. 2013; Shalabi & Turkan, 2017) and, as mentioned, this is predominantly owing to the restricted awareness of potential BIM benefits for FM among facility management professionals, lack of data exchange standards, unproven productivity gains and positive return of investment illustrated by real world case studies (Becerik-Gerber et al., 2012; Shalabi & Turkan, 2017). Nevertheless, as put forward, BIM in FM practices, could contribute to enhancing efficiency of work order executions by providing faster access to data (Shalabi & Turkan, 2017) and by improving the process of locating various facility elements via its user-friendly 3D interface (Becerik-Gerber et al., 2012; Kelly et al., 2013; Shalabi & Turkan, 2017;). In addition, carrying BIM from design to the facility management phase would help eliminate redundancy in data re-entry because BIM would act as a central data repository that supports all activities throughout the buildings' lifecycle (Shalabi & Turkan, 2017). Deploying BIM instead of artifacts to deliver as-built information could solve the disadvantages regarding static data delivery. The research by Çıdık et al. (2017) shows that in case Building Information Models are supposed to be used as the media for as-built information delivery, an Asset Information Matrix (AIM) should be specified by the client or their consultant before design models are produced. AIM defines the parameters for models, which objects should be included, which information should be incorporated and how the data should be structured and coordinated (McPartland, 2017).

Overall, it should be noted that BIM is not just a software, it is a process and a software (Azhar, 2011) and it enables closer collaboration between all stakeholders involved which could enable information sharing in an accurate and timely manner (Bryde et al. 2013). A knowledge transfer between facility managers and preceding actors such as contractors and designers and creating an information and knowledge transfer loop between mentioned actors could result in optimized operational and maintenance requirement in design of the new buildings (Becerik-Gerber et al., 2012). All in all, BIM provide a baseline for information management in the facility management stage which subsequent changes to the facility can be integrated to the model. Overtime, the model can be used as a rich history showing the records to the all components of the facility, so the property owner can use the knowledge in future business decision makings (Atkins & Brooks, 2015).

2.4 Theoretical lens

The purpose of this last chapter is drawing a connection between what have been already brought up and ground theories of organizational learning. Clegg et al. (2011) defines the organizational learning as a process of detection and correction of the errors. Organization learning also can be defined as a phenomenon in which processing a range of information causes changes in behaviors (Huber, 1991). Organizational learning is not the main scope of this master thesis and the research questions of this master thesis do not focus on behavioral change or learning processes. On the other hand, organizational learning encompasses four constructs. Information acquisition, information distribution, information interpretation and organizational memory and these 4 constructs function well to analyze the current information delivery to FM stage and that is why organizational learning is selected as this study's theoretical lens. First, knowledge or information needs to be extracted, afterwards, information needs to be transferred to other actors or organizations. The recipient of information should to an adequate extent understand and interpret this information and the last is organizational memory which is defined as documentation of those information. This master thesis is investigating as-built information and information required to be extracted and then included to make the as-built information a valuable document. Therefore, it can be justified how four constructs of organizational learning align with the scope of the master thesis and research questions. Hence, this master thesis is based on the 4 constructs of organizational learning and they are going to be used as a lens throughout the research when analyzing the empirical data.

2.4.1 Organizational learning

As already mentioned organizational learning is a process of detection and correction of the errors and it is achieved when knowledge of its members is explicitly known and codified by the organization. Knowledge is described as information, data, skills or more generally ‘’know-how’’ and is the most important strategic asset of organizations (Clegg et al., 2011). Knowledge enables organizations with a competitive advantage over their competitors, enhances organizational performance and brings success (Berg et al., 2012). Data, as Whyte et al. (2016a) explains, is unorganized facts while information is interpreted and present a meaning based on a specific context. In this master thesis knowledge and information are used interchangeably but they represent an explanation on an element or how a phenomenon is structured.
Huber (1991) elaborates organization learning divided by four constructs. information acquisition, information distribution, information interpretation, and organizational memory. The four constructs are each further elaborated.

2.4.1.1 Information collection

Çıdık et al. (2017) describe the organization of the built environment based on numerous interactions between social and organizational entities in which within a limited time frame project teams undertake collecting and managing large variety of information (Behzadan et al., 2016). By and large, in all the project-based accomplishments, structure of the information collection to establish which data and how those should be gathered, required to be defined by the client at the start of the project (Whyte et al, 2016b). However, it is a substantial work and quite challenging task to specify data requirements at the beginning of the project (Whyte et al, 2016b). In the interorganizational information transfer the problem is twofold since the donor organization should envision the future needs of other organization (Easterby-Smith et al., 2008). Anyhow, in both cases, Easterby-Smith et al. (2008) argues this information should add value to the recipient organization, so the donor should have something worthwhile, (i.e. Accurate and complete (Whyte et al, 2016a; Whyte et al., 2016b)) to offer which has been made available in an efficient manner (Whyte and Levitt, 2010). Therefore, information collection should be ‘’well planned, practiced and orchestrated’’ (Whyte et al, 2016b, P. 8). To achieve this, it should be noticed that the information acquisition in the AEC industry is a progressive work and progressive build-up of information should start in the design stage, with developing all along the life cycle to be close to a desired S curve (Whyte et al, 2016b).

2.4.1.2 Information distribution

Information distribution is the second construct of organizational learning. An organization satisfy its information need by receiving the appropriate information from other organizations or another unit within the organization (Huber, 1991). Knowledge and information transfer within a project between involved organizations is a prerequisite for successful project delivery to the clients and more effective project performance (Berg et al., 2012; Whyte et al, 2016a; Whyte et al., 2016b).

Back to the context of the AEC industry, the organizational transfer of information from project to FM stage is of significant importance owing to the FM activities' productivity and efficiency and needless to say the cost bound to those documents of information (Hardin & McCool, 2015; Kassem et al., 2015). Also, by receiving different information from different organizations and by connecting them or interpreting in new ways they become able to form new information creating new value for the organization (Huber, 1991; Whyte et al., 2016a).

One challenging point here is that in the AEC industry might not be any temporal overlap between the group completes their activities and disengages, handing the information over to another group that engages to conduct related but different activities (Whyte et al, 2016b). Another important aspect of information distribution is checking data accuracy. The AEC project-based industry is criticized for bypassing the controlling information accuracy to speed up their own work (Whyte et al, 2016b) or as Hardin and McCool (2015) describe it ‘’checking the box’’ at the hand over to complete the contract. This will contribute to creating distrust toward received information. Also, bypassing the controlling information accuracy by the inspectors at the handover of the project results in repaying to gather the same information in the time of survey or renovation (Kassem et al., 2015)

Moreover, Other factors affecting the effectiveness of knowledge and information transfer are multifaceted nature of the boundaries between organizations, culture and their absorptive capacity (Easterby-Smith et al., 2008). Also, a variety of stakeholders engage in the construction projects such as clients, contractors, subcontractors, and other suppliers which makes the communication and transfer of information quite complicated (Bosch-Sijtsema & Henriksson, 2014). Therefore, sequence, timing, handover technique and communication of information is something that the project team should take into consideration in the start of the project (Whyte et al, 2016b). In case information transfer happen in both directions (Easterby-Smith et al., 2008), in this context from design to FM and vice versa, it leads to fully closed loop between design, construction, and FM operations data which enables utilizing lesson learnt from the past projects in the new projects (Becerik-Gerber et al., 2012).

2.4.1.3 Information interpretation

Interpretation is defined as a process in which information is given a meaning (Huber, 1991). Complete understanding and common interpretation over different information elements could result in effectivity in the use of information. One key factor affecting over understanding different information elements is the organization's absorptive capacity. Absorptive capacity is the extent of ability the recipient organization have to understand the value of the information and to what extent can utilize the new information (Easterby-Smith et al., 2008). In the context of project-based AEC industry at the close out of the project contractors transfer As-built information to the clients for the maintenance and operation of the facility (Whyte et al, 2016b). The facility managers will be able to fully deploy this information if they assimilate and interpret it correctly. Therefore, existence of a communication media to construct shared meaning between the donor and recipient of the information is quite essential. Fragmented use of data and lack of sufficient collaboration between involved organizations inhibits creating a common understanding between the donor and recipient of the information (Easterby-Smith et al., 2008). Another challenge toward information transfer is information overload. If the information sending to the construction clients exceeds their capacity to process the information, they might have problems interpreting and extracting their required information (Huber, 1991).

2.4.1.4 Organizational memory

Information generated throughout the project or received from other organizations should be stored in the organizational memory. The rationale behind organizational memory could be defined in three aspects. One is the anticipation of future needs which leads to storing certain type of information which is going to be used at a later stage. The second is the prevention of turnover loss which is documenting existing knowledge or information. Therefore, when the personnel, in this context a facility manager, leaves information still remains in the core organization and handed in to the next facility manager. And the third is organization's members will be aware of the location of the information and be able to retrieve the information they need (Huber, 1991). After the process of information creation and transfer, the shared information should be stored in a way which makes the activity of information retrieve effective and efficient (Whyte & Levitt, 2010). As Huber (1991) argues many organizations often do not know what they know, and this is due to complexity toward looking for needed information in their organizational memory. Unsatisfactory indexing is another factor which results in lessening utilization of the stored knowledge.

3 Methodology

In this chapter, the applied method for this study is presented, including justifications for the choices made, in order for the reader to understand the adopted procedure. The aim of this chapter is to assure the quality of this thesis and allow readers to reproduce the enacted study.

3.1 Research approach

The primary purpose of this master thesis is to explore and explain the current situation of as-built information delivery. As a result, collecting and analyzing the empirical data have formed the initial steps of the master thesis. Hence, the inductive research method is adopted owing to the fact that it suits exploring a research subject and developing theoretical propositions out of the gathered data (Mason, 2009). In addition, by expanding authors' understanding of empirical findings and developing themes out of the gathered data (Creswell, 2009) and analyzing it, theory and knowledge could be generated. (Bryman & Bell, 2015; Mason, 2009).

Moreover, to accurately address the type of inquiries formulated in this research, a qualitative research strategy has been adopted. The aim of qualitative research is to achieve an understanding of how actors make sense of their situation and describe how they interpret what they experience (Merriam, 2009). Creswell (2009) associate qualitative research strategy with social constructivism in which the authors' intent is to make sense of the views and meanings participants create about the concepts and, therefore, develop a theory based on the patterns of meanings. The choice of the method should be based upon the nature of the research problem and this method corresponds well to what is suggested by Merriam (2009) since it tries to make sense of what actors interpret and define as required FM information and challenges toward the as-built information delivery. Overall, qualitative research strategy is well associated within the inductive research method in which the emphasis is on the generation of theories and ways in which individuals interpret their social world (Bryman & Bell, 2015).

3.2 Research design

A cross-sectional design is defined as a method of collecting data on a few cases at a single point in time (Bryman & Bell, 2015). There exists a variation toward the participant's statuses and entailed organizations in this master thesis. Also, there is a variation toward the studied elements. The cross-sectional design is applied in relation to the qualitative research strategy and semi structured interviews to suit the research design with research strategy. Therefore, within a cross-sectional design study designer, contractors, BIM specialists and property managers who are key actors delivering and receiving the as-built information were invited to the interviews to share their insights.

3.3 Theory and literature review

In this master thesis and as already mentioned in regard to the inductive research method, theory is considered as a notion emerging out of the collection and analysis of data, involving attempts to comprehend embeded patterns rather than to impose preconceived ideas on the data (Bryman & Bell, 2011).

The literature review in this thesis was mainly established on scientific books, articles and a few conference papers. Most of the literature was found in Summon Chalmers Library, and Google Scholar yet a number of them were directly provided by the master thesis supervisor to the authors. Key words which the authors have used to look for the literature include: as-built information, as-built drawings, BIM, BIM at FM, Building Information Modelling, Facility management practices, Non-proprietary format.

Since BIM and its implementation for as-built information delivery could be realized as an evolving concept, our first criteria was to look for the articles published in the last 5 years. However, there were few articles to assess implementation of BIM at FM which has to some extent limited our resource selection. To back up the resource selection and maintain the research validity older publications were opted based on the number of the citations. Also, compatibility to the Swedish AEC industry was the last principle of the master thesis criteria to find relevant literature. Hence, concepts which are not compatible with Swedish industry has been filtered out. The initial steps toward literature review were essential to form the research questions, make the interview guide and interview questionnaire for FM actors. After conducting the majority of interviews based on the data from empirical studies the literature review was conducted to build the preliminary theories and text to approach our research questions.

3.4 Interviews

While adopting a qualitative research approach interviewing is the most frequently employed method (Bryman & Bell, 2015). The inherent flexibility of interviews is what makes it attractive. A semi-structured interview format does not allow for the same focus on reliability and validity in regard to structured measurement of key concepts, which would be the strength of a quantitative interview approach. However, given that the objective is to understand a topic which does not allow formulation of structured measurements of key concepts but rather focus on greater generality in the formulation of research ideas and on the interviewees perspective. One aspect of interviewing within a qualitative research setup is that going off the topic is encouraged, since this will give insights to what the interviewee sees as relevant and important. Therefore, as (Creswell, 2009) recommends open ended interviewing were adopted synchronized with qualitative research strategy to facilitate exploring the subject and participants views.

Since the aim of this research is focused towards the handover of information two key actors have been identified, the actor delivering, and the actor on the receiving end of the transaction. Also, a third actor, BIM specialists, were interviewed to investigate implementation of BIM as a media for as-built information delivery. Moreover, three similar semi-structured interview guides have been formulated in order to facilitate the analysis of the interview material and eight interviews were conducted, transcribed and analyzed to build up the result chapter. Table 3.1 present all the interviews and the actors background. Also, the interviews were complemented with a questionnaire which was sent to FM actors in order to realize the type of information they need and to assess the impact of current information delivery on their FM practices. Following table present all the participants and brief description on their expertise. A more complete description on the area each interviewee is working with the recent projects they have been involved is attached to the appendix 8.1.

Actor	Active phase	Company profile	Work specification	Current BIM use
A	Construction	Construction company	Construction manager	Active for production stage purposes
B	Construction	Construction company	Construction manager	Active for production stage purposes
C	Design/ Construction	Construction company	Design manager	Active for the design and production stage
D	FM	Public housing company	District manager	Very limited
E	FM	Hospital facility management	Technical manager	Very limited
F	FM	Property owner company	Project developer	Use BIM in their request policy
G	BIM	BIM consultant company	BIM strategist	Focus on BIM implementation and support
H	BIM	Design consultant company	BIM coordinator	Focus on BIM implementation and support

And the following makes the structure of the three interview guides.

General, in order to understand the context of the projects the interviewee is active in some general questions have been formulated.

As-built information, the core of this research is built upon the as-built documentation and the information included in the handover between construction and operation, questions have been formulated in order to get a better understanding of the process.

Required information, the aim is to find out valuable information in the FM stage.

BIM, the technological opportunity that is provided by BIM is suggested to enable dynamic as-built information.

The table 4.1 and the chart 4.1 is the result of the questionnaire. It should be noted that all participants answered all the questions regarding the table 4.1. However, two of the participants did not respond to all the questions regarding the chart 4.1. Therefore, the result from the chart 4.1 is not as widespread as the table 4.1. All the questions and answers regarding chart and table 4.1 is submitted in the appendix 8.4

3.5 Data analysis

In order to manage and categorize the large data from the eight conducted interviews, the coding method was adopted. According to Saldana (2011) coding is a heuristic method to classify data into patterns to gain distinct categories for data analysis. Therefore, this study follows Saldana (2011) instructions by putting the recognized patterns into categories. Saldana (2011) describes a code as a word or phrase which assign an attribute for a visual data. Afterwards, four categories were selected, each of them associated with a research question. Through those categories, similarities and differences were identified in order to organize the result chapter in a more solid manner and also to build up the structure for the further analysis in the discussion chapter.

3.6 Reliability and validity

In the business and management research, reliability is attributed with the question whether the result of the study is repeatable in the future studies (Bryman & Bell, 2015). As Bryman and Bell (2015) state, reliability criteria which is most often related to the quantitative research method, is concerned with the fact that if measures framed for the subjected concepts are consistent or not. Also, the other important criteria for a research is validity. According to Bryman and Bell (2015) ‘’Validity is concerned with the integrity of the conclusions that are generated from a piece of research’’ Bryman and Bell, 2015, P. 42). Nonetheless, Saldana (2011) refer to reliability and validity as two constructs of the quantitative research and use the two criteria ‘’credibility and trustworthiness’’ to be better tailored to the qualitative research method. Moreover, Saldana (2011) suggests a few methods to attempt gaining credibility and trustworthiness. One is to use the coding method while going through interview transcripts to have an established framework for data analysis. The other is data corroboration which is sending the interview transcript to the participant for further revision to make sure understating the participant’s points of view precisely. However, the second was only carried out in case the interviewee themselves had the encouragement to read through the transcript. Overall, the authors attempted to observe the credibility and trustworthiness criteria and admit that this study as a master’s thesis does not aim to prove any factual statement. Instead it strives to approach data analysis as objective as possible to reach a convincing suggestion to the existing problem.

3.7 Ethical aspect

The ethical principles in a research project is expressed in four prepositions. First one is consideration whether the research does harm to participants. This harm could be physical, emotional or carrier prospect. The second is the participant should explicitly express their consent to participate in the research. Disguised observation in which covertly observing the participants is regarded unacceptable. The third is transgression of the participants’ privacy, respect and rights. The fourth is whether deception is involved in the research. It happens when researchers display their research as something different of what it actually is (Bryman & Bell, 2015).

The authors’ strategy to observe the ethical aspects has been approaching the participants with clear explanation on the purpose, content and objective of the master thesis. The identity of interviewers and the program and school that they were doing research for were revealed quite before the interviews. Also, a copy of the research questions and interview questions were sent to each participant, therefore, they became acquainted of what would be discussed. Also, they were consented interviews to be recorded for the further interview transcription. After all, to mind their privacy, the identity of the interviewees and the companies involved have not been disclosed in the master thesis.

4 Results

Results presented in this chapter are based on interviews that were held with various actors active in the Swedish AEC industry. The intention with the decision to approach actors active in various phases of the facility life cycle is to understand the handover of as-built information. The results are hereby presented in the following categories: current practice of as-built information delivery, FM required information, as-built information delivery challenges and BIM-supported as-built information deliveries. All respondents have the background connected to the delivering of as-built information respected to their position and the authors have tried to present their unabridged point of views objectively. A matrix based on parameters which aim to clarify the context in which the various actors are performing their work has been created and presented in the methodology chapter.

4.1 Current practice of as-built information delivery

The current practice and procedures of as-built information delivery is understood as being rather similar between different building projects, even if some variations have been presented among the actors involved. The documents which are delivered in the swedish AEC market are Drift och Underhålls (DU) instruktioner, literally translated as operation and maintenance instructions, and Relationshandlingar, corresponding with as-built drawings.

Construction manager B defines the operation and maintenance instructions in general as ‘’what the client needs to know for the operation and maintenance purposes’’. Nonetheless, the content of operation and maintenance instructions varies based on the use of facility. For example, as construction manager B explains, hospitals with many different operational equipment and technical devices consist of enormous amount of operation and maintenance information, whereas operation and maintenance instructions for a flat is not nearly the same. More specifically, the format of delivering as-built information is based on the client’s request. As construction manager B argues it differs what type of clients you have and how professional they are. Based on the interviews with the construction managers A and B and design manager C, in most cases clients have asked for a folder of printed documents of operation and maintenance instructions and as-built drawings in PDF and DWG file format. However, recently, it has been cases in which the client instead has asked for Revit models or (3D) IFC model at the end of the project. However, regardless of both cases, everything should be specified early in the contract. As construction manager A admits:

‘’Normally it is written down in the contract in the so-called AF-delen (administrativa föreskrifter), which information we should deliver to the client and it is quite regulated, which information in what format, how many copies and when we have to deliver all the information.’’
(Construction manager A)

Nevertheless, and as mentioned the procedures are rather similar. The designers transfer the drawings and technical specification and description on how to construct the facility (Bygghandling) to the construction managers and they construct the project based on the received document. During the construction phase, contractors are responsible to get all the information from the subcontractors and suppliers and integrate that information to the as-built information. As construction manager B explains they mostly download it from the suppliers’ homepage. Moreover, all the materials used in the project by the main contractor or subcontractor should comply with the regulation provided in the BVB assessment (Byggvarubedömning/ https://byggvarubedomningen.se/in-english/).

Regarding the as-built drawings, the update is carried out through communication between the contractor and the designer. For example, when there is a mismatch between the drawings and specifications or there are clashes in the drawings or something should change due to the buildability problems, the contractors communicate the issue by sending a document to the related designer and if confirmed, they carry on construction based on the new input. However, this is the corresponding designer's duty to integrate those changes to the drawings. By integrating the updates to the record drawings which are detailed design drawings, the as-built drawings are obtained. At the project handover to the client, construction managers provide the client with the final version of operation and maintenance instructions and the as-built drawings. So that the inspector (besiktningsman) controls all the documentation and verifies the information that the contractor delivers and if confirmed then the documents are handed over.

4.2 FM required information

The aim of this section has been benchmarking the types of information which are valuable for FM practices and activities. All eight interviewees were approached based on their expertise and backgrounds and were requested to share their perspectives on the issue.
The initial question regarding this section has been the delivery policy of the information within their respective firm and most of the interviewees have given the authors a common respond.

''The required information can vary a lot between projects depending on what the use is going to be''. (BIM specialist G)

The construction manager B who has been working in Sweden and Norway for more than 30 years also admits the information required could vary from project to another project and from client to another client.

''Normally we follow the client's request. if they ask for the drawings or maintenance information or how to use technical devices. But it totally differs based on the project to project and the clients. normally it differs what type of clients you have and how professional they are.''
(Construction manager B)

When asking the question to the property managers, property manager D says that their request policy is specified in terms of what they should contain, however, it is not project specific, a standard for all the projects has been produced. Property manager F also states that they have a request policy which is consistent in all the projects that he is responsible for. He continues they always request for the as-built drawings, all the construction calculation, energy consumption calculation, material used, system design and function descriptions, and other operation and maintenance instructions. Property manager E mentions that request policy regarding as-built information is tailored to the operation and maintenance activities. In their operation a concept is formulated in the DU instructions, based on this concept consultants specify to the contractors what they need to deliver. In comparison, property manager E provides the authors with a more solid framework of which information they specify in all the projects. The framework consists of as-built drawings, system design and function descriptions, operation and maintenance instructions, Protocols, lists, certificates and safety documentation, List of installations, Material type, Warranties, Product data sheet, Hydraulic calculations, and Software.

Nonetheless, BIM strategist G, design manager C, and construction managers A and B, unanimously believe that most clients often do not clearly know what information is required for FM. BIM strategist G and design manager C argue that it is a complicated task to specify which information is needed for the FM at the start of project. As a result, in a refurbishment project the client decided to bring up a consultant to specify the information needed for the FM. Therefore, BIM strategist G is assigned to identify what information should be included in the as-built information to benefit FM. He shares his approach on the task of specifying the required information. He describes there are three aspects to be considered when fulfilling that task. Legislation, current practice and the specific future needs of the client.

''First the legislation, there are EU directives, Swedish local laws and there are municipality-based laws. For example, you should inspect the elevators every year and then you should protocol it using this format. So, first legislation, and then current practice. We go to the site, we investigate their current databases, what do you have now, what information are you using daily, what information do you store, and how do you store it. And afterwards future needs, we would ask FM practitioners, how would you want to improve your work practice with information, and it's not as easy as just asking a few questions, you have to really dig in to what they are using''.
(BIM specialist G)

Furthermore, construction managers A and B and design manager C were asked regarding how proficient their firms are to provide the information clients need and what is the most frequent type of information clients ask for. All three subjected interviewees firmly state that their firms are capable of meeting all the requirements issued in the drawings and technical specification and descriptions. Construction manager A who has been working as a facility manager for a few years in Germany believe that most important and frequent type of information are the as-built drawings since the client is required to deliver to the municipality for the building permit (Bygglov). She continues their recent client asked for function description which is for example how the ventilation system works and maintenance information for example how to service that. Construction manager B mentions the above type of information; and he continues calculation on the energy usage of the buildings, warranties, and material type used in every element are other sort of information most of the clients request for.

Nevertheless, to benchmark the valuable information required at FM stage, all three property managers, and BIM strategist G were provided with a questionnaire. The reason why BIM strategist G participated in the questionnaire is that he is working professionally on the task of identifying valuable information at FM stage. Moreover, eight different type of information were recognized based on the literature and the interviews with all actors. They are Dimension, Geometry, Material type, Design life, Warranties, Information on the building energy performance, Function description of the building's components, and Administrative cost. To understand the importance of this categories of information 4 questions were designed as:
1. Which of the following types of information are more critical in the time of refurbishment? (Grade from 0 to 5 and 0 is the least critical and 5 is the most critical)

2.Which of the following types of information are more critical in the time of maintenance and repair of equipment (for example reflection concerning to trouble calls (i.e., a room is too cold, or pipe is leaking)? (Grade from 0 to 5 and 0 is the least critical and 5 is the most critical)

3.-Which of the following types of information is more frequently needed within your everyday basis? (Grade from 0 to 5 and 0 is the least critical and 5 is the most critical)

4. What sort of information do you provide to your users? (sustainable performance, energy usage, etc.)
The complete questionnaire is provided in the appendix 8.4. Interviewees were asked to grade the information from 0 to 5. Zero stands for not at all critical and 5 stands for the most critical. Below table is the result of their grades on the four questions.

	Dimension	Geometry	Material type	Design life	Warranties	Information on the building energy performance	Function description of the building's components	Administrative cost
Property manager D	5	4.25	4	2.5	0.5	2.5	4	4
Property manager E	3	3	3	.75	4.3	4.7	4	3.5
Property manager F	4.3	4.3	5	4	5	4.5	5	2.25
BIM strategist G	4	4	3	2	3.5	3.5	5	2.5
Total	4.15	4	3.75	2.3	3.85	4	4.5	2.75

Table 4.1

Property manager E realized Warranties, Information on the building energy performance, and Function description of the building's components more critical. Also, regarding controlling the energy usage of their facilities they had a structured approach. He says:

''Everything is specified in the technical standard, which gives you everything, how it should be marked, the dimensions that should be used, and the requirements including energy usage and what should be done to bring down the energy consumption.'' (Facility manager E)

On the other hand, Property manager D grade Information on the building energy performance just below the medium. He argues that the energy performance of the buildings is very far related to the tenants' behavior and that is hard to evaluate when assessing the life cycle costs. Property manager D grade the Dimensions the most critical because of the frequent use. Arguably, renting out the apartments, setting the price on the apartment, determining taxes, and a lot of governmental regulations is dependent on dimensions. Quite unlike property manager E, property manager D does not consider information regarding warranties as indispensable. The reason is the apartments is warranted by the constructor for a period of time so in cases an equipment goes out of order they just contact the supplier. Anyhow, toward argument of property manager D, the BIM specialist G acknowledges that in the Swedish market there is a regulated rent for apartments and the demand is huge, so property owners already make a lot of money in this market and they have low vacancy rates, therefore, investing in information would be lower priority than in commercial spaces. BIM specialist G grades the Function description of the building's components the highest possible as a vital piece of information which is required in any type of project.

To conclude, last row of the table 4.1 depicts that Function description of the building's components is ranked first in terms of importance with Dimension, Geometry, and Information on the building energy performance following that respectively. Anyhow, as property manager F believes all the eight type of information should exist in the as-built information. However, the authors decide to round off this section with a comment from BIM strategist G on the required information at FM stage.

Overall, the required information could vary a lot between projects depending on what the use is going to be. The key is to find a level where you can scale it up or down easily, so that you will not have to invest and decide in the planning stage what information you are going to have future on, so that is the key I would say. (BIM strategist G)

4.3 As-built information delivery challenges

The work connected to delivering information from the construction phase to the (FM) phase implies a few challenges and the aim of this chapter is to present the challenges identified by the different actors. Delivering the information required in the hand over is a task that involves several actors, even in projects which are not very complex. Therefore, challenges of different nature emerge. Another implication connected to the fact that several actors are involved in the delivery is that this process often becomes fragmented.

One quite initial challenge to deliver as-built information is something that several actors point out unanimously. The Construction manager B bring that up as the client is not aware of what operational and maintenance information they need for facility management activities. As a result, they are unable to specify that in the initial stages. It would be crucial to provide project specific information rather than just the generic specifications formulated on an organizational level. Design manager C and BIM strategist G also acknowledge that, and they have been engaged in projects in which clients recruit a consultant who have been assigned to determine the operational and maintenance information in the beginning of the project. Involvement of the facility management expertise in the early stages of the facility life cycle is something that few of the actors have extensive experience with, even though this is something that has been acknowledged as necessary by some of the actors.

The second noticeable issue concerned to as-built information delivery is the difficulties associated with retrieving the information with the delivered format. Authors have asked both construction managers what is most noticeable challenge with as-built information delivery and this response from construction manager B has been similar in both responses.

''Facility managers cannot find the information they need. For example, sometimes in apartments there is some blockage in the pipe, so they call and ask how we can fix this or where is the pipe going or what is the material of the wall, is it a concrete wall or is it a gypsum and how we can open it. So, they call us, and we have to send someone to check on it although answer to all of these questions is provided in the operation and maintenance instructions''. (Construction manager B)

On the other hand, property manager E claims that the problem with retrieving the information is that the contractors do not hand over all the required information. For instance, getting complete functional descriptions is of the essence in their workflow and in cases the description is not provided in the maintenance and operation instructions they will have difficulties to understand or achieve the information themselves.

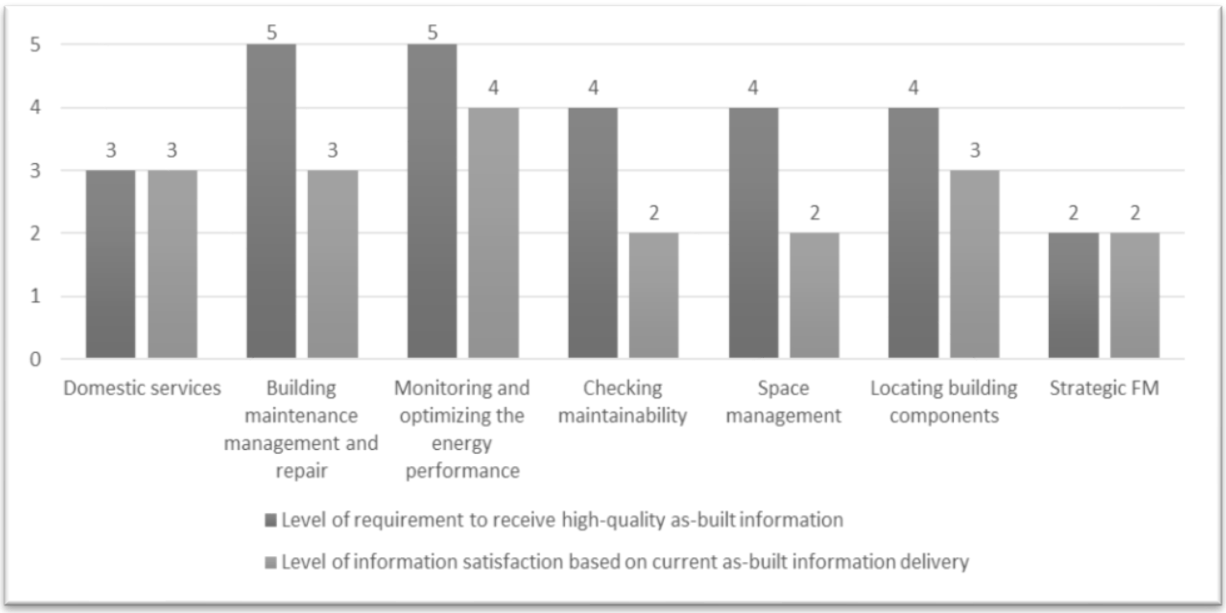
The third problem which is confirmed by property managers E and F is the overload of information. Property manager E states that when they receive the as-built information, they have to go through the documents and narrow down the information to find the required information to upload into their facility management system. This is problematic in cases all the data from the preceding phases is transferred to the FM phase. This is complemented by BIM specialist H and BIM strategist G saying that all the generated information during the construction period is not interesting for all the actors and all the phases of the life cycle.

Design manager C and construction managers A and B refer to the forth problem associated to current information delivery and that is the quality of as-built information is very much dependent on the accuracy of construction manager's work. Property manager D and F confirm that sometimes they receive drawings in which markups are drawn manually and information is rarely spot on and yet occasionally they receive adequately accurate as-built information. One related problem with varying quality is owing to accuracy of inspectors' work. Property manager F claims that they have struggled with not having professional inspectors and, therefore, they have aimed to develop a solution for meeting the verification of the as-built information by accessing to competent inspectors. Property manager E acknowledge that the as-built information in most cases is not verified and admits that for a facility like a hospital the correctness of information is indispensable. The mentioned issue becomes more substantial when considering BIM strategist G point of view saying that verification is the key in as-built information delivery since it brings trust to the documents. Below quote from property manager D complements this section.

"When we get the as-built for a new building we don't go out and measure it, so it is usually a few years later that we realize what the quality is, when we do some changes."
(Facility manager D)

The fifth and last challenge is the update of as-built information delivery. Keeping the data up to date over time is a challenge both during the construction phase and after the handover at the FM phase. Construction manager B refers to update of as-built information a challenging work since they have to do it regularly throughout the project. And in addition, they mention that there is no real incentive to dedicate efforts exceeding a sufficient quality. As mentioned in the second subchapter, update of information is carried out through the communication between the construction managers and design managers and design manager C argues that he does not receive accurate markups most of the time. Update at the FM phase is another issue as BIM strategist G explains the technician who does the change, usually it is a very incremental change, and they forget to report that to the FM and the information is not updated. And that is why facility manager E explains they do not usually update their information unless it is a very substantial change in the facility.

To conclude and to understand the impact of challenges on the workflow of FM actors, FM actors and BIM strategist G were asked to grade the level of information requirement on the seven recognized FM practices and how satisfied they are based on the current as-built information delivery. The chart 4.1 presents the results.



As visible only two practices have their information needs satisfied with the current practice of as-built information delivery. Also, building maintenance management, checking maintainability and space management presenting a greater need for more high-quality information delivery.

4.4 BIM supported as-built information delivery

The aim of this section has been to investigate the procedure for implementing Building Information Modelling as the media for as-built information delivery. The BIM strategist G believes the preliminary reason to utilize BIM as the media for as-built information delivery is that BIM provide a structured process to create planned information delivery. He claims that the identified operation and maintenance information is quite hands-on which should be accessible to perform FM daily practices. As a result, more efficient workflow at FM stage is concluded. The design manager C also mentions the importance of creating easy access on the required maintenance information yet points out to the fact that storing information in non-proprietary format enables utilizing the information across the life cycle. In this sense, as BIM specialist H explains each discipline would create a corresponding IFC schema handling specific as-built information. In addition, BIM strategist G describe the as-built information models as an asset which could be sold alongside the facility. He declares:

‘’*When selling the facility, this asset information could provide information that could enable the buyer to do a very good analysis of the upkeep cost. And that is among the most paramount values of having the structured information.’’* (BIM strategist G)

Moreover, BIM strategist G and design manager C have been involved in projects delivering Building Information Models presenting as-built information to the FM stage. Experience of both interviewees is shared below to shed a light on the delivery procedure. The clients for both projects have been two different large retailing companies. In project G, which is a refurbishment building project in Sweden, BIM strategist G is assigned to work as the client’s FM consultant, to define the structure of data in models, which objects are needed to be included in the models and investigate which information is required for FM stage to be attached to those objects. In project C, which has been a new constructing commercial building in Norway, design manager C was assigned to collaborate with the client’s FM consultant to deliver Revit files to the FM stage. In the latter case as well, the client’s FM consultant were responsible to define the structure of data in models, which objects are needed to be included in the models and investigate which information is required for FM stage to be attached to those objects. In the case of design manager C, he describes his experience below.

‘’The client’s FM consultant came up to the project early in the design phase (and specified which information is needed for the FM phase) and told us how to describe the BIM objects for the use at the FM phase. So, he went to the different disciplines and defined how the models should be structured and labeled. The work started in the design phase and was produced for the entire (life) cycle, so we continuously updated (the models) during the process. And when we were finished with the building, we delivered the models and one IFC from each discipline.’’ (Design manager C).

Design manager C states after handing over the models to the property owner, facility manager was supposed to maintain the models and update it. In case of big changes like a refurbishment, new Revit models would be created and through the updated models, new IFC files would be attained. However, BIM strategist G sees flaws in this way of updating information. He comments on this procedure as:

So, that would be the traditional way to perceive it and a lot of people have been saying that it would not be a viable way to do it. There are a lot of implications with using the data at FM and one would be keeping the data up to date over time. If you change something in the physical environment you are required to change that in the virtual environment as well and the tools for doing that is not really developed for that purpose. In other words, BIM software is not designed for FM to update incremental changes. Instead, they are developed to create the planned data. (BIM strategist G)

BIM strategist G further takes the Sydney opera house as an example.

I went to the Sydney opera house and they have been doing this for years, because there are changes in the facility all the time and when there are small changes, like moving a fire extinguisher, they have to update that in the Revit environment and that is very expensive (and) they have several BIM employees sitting constantly updating the model. Revit is not designed for this purpose, easily changing the information, so it is going to be very expensive and it requires special competencies. And the technician who does the change, maybe it is a very incremental *change and he forgets to report that to the FM, then we cannot really trust the models anymore. If only one percent of the model is inaccurate you cannot really trust the rest of the ninety-nine percent.* (BIM strategist G)

Overall, validation of the models is the key to use BIM as the media for as-built information delivery. Whereas design manager C is accustomed to the idea of assigning an architect to sit on construction site, integrate new information and update the model during construction processes to deliver at the end of the project, BIM strategist G puts forward another approach. He firmly states that more efficient and accurate validation of as-built information is the most vital aspect. He believes at the end of the project a laser scanning would be a better approach to get the all dimensions and geometry. Therefore, all the other required information would be obtained from previous models and of course additional information generated from the different suppliers which is related to the FM would be stored to the models. BIM specialist H states that transferring all the information from the design and construction stage to the FM stage would lead to an overload of information to the facility managers since facility managers are only interested to the operation and maintenance information and not all the information generated throughout the life cycle.

However, not all the interviewees have the same disposition toward implementing BIM as the media for information delivery. The property manager D believes that the current technology which BIM provides is not sufficiently beneficial to rationalize the investments for implementation at FM. For example, he explains the data they receive from the contractors is just basic which justifies adding that manually to the facility management system. Also, he argues there is not much of a value for them to know where the water lines are exactly located behind the wall. Despite that, he claims they would need more sensors to capture data where the leakage is located and that is where BIM could bring value to the organization. The property manager E states that currently they only receive the documents in the PDF and DWG format. Although he remarks that they will use BIM as the media for as-built information delivery in the following years, he explains the reason why they have not adopted BIM yet is BIM results in information overload and since they are in charge of managing the information for 11 hospitals the overload would be huge. Also, He argues the models should be updated all the time and as they have many hospitals under charge it would be a large amount of cost.

On the other hand, property manager F states that in the current building projects they are asking for as-built information in Revit format. He believes that Revit provide a setting in which all the needed information could be attached to the associated object but still there are inefficiencies. For example, even though the information from IFC could be directly transferred to their facility management system, they do not use IFC since when converting Revit to IFC some mismatch of information appears. However, regarding this issue BIM strategist G claims if BIM specialists define the structure of data in the models accurately, the problem will not appear. property manager F states that if the problem of mismatching the information between different format would be overcome, then it could lead to more efficient use of BIM in information management. As an example, he says that by implementing non-proprietary format they will be enabled to connect different data within other information systems in the company. He states this can lead to creating new information as getting new economical patterns, impact of material used in the design, and even environmental information.

Overall, this section is concluded with the BIM strategist G point of view claiming that if BIM is supposed to be employed at the FM stage, BIM should be adapted to the FM and FM should be adapted to BIM. He believes if property owners believe that they need more complete and accurate information delivery, they should appraise adopting BIM-supported information delivery and in return BIM could be adapted to be more tailored to the specific requirements and features of FM.

5 Discussion

The following chapter presents the discussion and analysis and aims to confront the empirical findings in the previous chapter with the theories put forward in the theoretical framework. It has been attempted to keep the same structure as the result chapter to facilitate understanding the similarities and differences between the theory and the practice.

5.1 Current as-built information delivery

To start the first section of the discussion chapter it might be worthwhile to remind the initial problem the thesis is investigating. It was studied that the AEC industry is a project-based industry in which during a limited period of time a variety of stakeholders cooperate with one another to deliver a project to the facility management stage (Azhar, 2011; Bosch-Sijtsema, 2014; Bosch-Sijtsema & Henriksson, 2014; Shalabi & Turkan, 2017). Also, the issues like fragmented use of information and poor information recording and sharing is identified as the difficulties the industry is coping with (Bosch-Sijtsema, 2014; Bosch-Sijtsema & Henriksson, 2014; Çıdık et al., 2017). These issues were affirmed based on the empirical data in which the contractors realized the property owners as the party which should step up to improve the information delivery and in return property owners claim that they expect more effective information delivery from the contractors.

Having said that, based on the collected empirical data, Swedish AEC industry has shown a growing awareness about the importance of necessity of the as-built information delivery. As an example, the required information and format is specified early in the contract although the requested information in most cases is quite generic. The requested documents in the contracts are rather established and a few of the property owners understand the fact that they do not need all the documents generated in the design and construction stages rather they shall require for more specific information to which suits the operational and maintenance practices. Also, the contractors present an appropriate appreciation on how and what to deliver although there does not exist formulated demand from the clients yet. To exemplify, most often contractors realize the fact stated by Whyte et al. (2016b) suggesting that as-built information collection should be considered as a progressive work in which should follow a desired S curve. Nonetheless, there have been cases in which contractors postpone collection of the as-built information to the last few weeks to the hand over. Anyhow, the fragmentation in the industry and toward the use of data is seen as a long-lasting challenge which affect the as-built information delivery which developing a solution to meet the dragging challenge is understood quite essential.

5.2 FM required information

As Çıdık et al. (2017) and Whyte et al. (2016b) declare specifying data requirements for the operation and maintenance activities is a quite challenging task. Interviews provide the authors with the similar notion that the property owners have difficulties to specify which operation and maintenance instructions they need, early in the project, to issue in the contract. Therefore, in many cases they request enormous number of documents produced in the construction phase which some have little value to FM practices. This easily leads to information overload which is discussed in the next section as a cost intensive culprit. As elaborated previously in the theoretical framework, the quality of this information is quite critical as accuracy of the information is considerably essential in the informed managerial decision making (Shalabi & Turkan, 2017), prompts action when needed (Róka-Madarász et al., 2016), and improves the efficiency of the facility management processes (Becerik-Gerber et al., 2012). Therefore, the required information should be specified with extensive considerations. Based on the empirical data, these extensive considerations include legislation, current practice and the specific future needs of the client. Overall, it is understood that the task of information specification needs a suitable expertise and competence and it could be considered, at least in more complex projects, in a way that clients assign a consultant to perform the task on behalf of them.

Furthermore, the perception declared by Hardin and McCool (2015) stating that required and valuable information for the facility management purposes differs based on the diverse types of the facilities, is unanimously reinforced by all the interviewees. However, a new concept was proposed in the interviews by BIM specialists. It was claimed that the critical factor should be to find a level of information delivery where it could be scaled up or down easily based on the project requirements. Therefore, it could prevent unnecessary investment in the planning stage to recognize what information will be needed in the future. Providing a baseline which benchmarks what information is vital for the facility brings another benefit and that is, it decelerate the information overload. Based on the interviews, majority of property managers asked for all the construction calculations in the as-built information which is not greatly useful at FM practices. Not surprisingly, those property managers mention that information overload is a factor that they deal with every day in their department. While maintaining the reliability and validity of as-built information is considered essential (Atkins & Brooks, 2015; Whyte et al., 2016b), maintaining the data which has little use to the organization could be costly (Whyte & Levitt, 2010). Therefore, defining the level which baseline the required information is beneficial but as (Whyte et al, 2016a) state that needs an organized way to prevent overload of information yet create value to the owners.

5.3 As-built information delivery challenges

In this section and the following section, it was preferred to confront the findings from the empirical data to the theoretical framework based on the four constructs of organizational learning. The logic behind has been to analyze the challenges in a more scrutinized manner to create a better conclusive perspective on the issues. Hence, all the challenges found in the result chapter are elaborated using the theoretical lens below.

5.3.1 Information collection

The information acquisition is aspired to boast an efficient workflow (Whyte & Levitt, 2010) and collected information is supposed to be accurate and complete (Whyte et al, 2016a; Whyte et al., 2016b) to make a purposeful document to offer to another organization (Easterby-Smith et al., 2008). However, based on the interviews, property managers are not satisfied with the quality of received as-built information and argue that information accuracy depends on the quality of construction manager's work. One possible explanation based on empirical data might be that there is no real incentive to dedicate efforts to achieve a satisfactory quality. However, another possibility could be that current information collection workflow is not adequately efficient. As an example, as-built drawings are obtained in a quite error-prone fashion in which construction managers manually measure changes and inform the designers to update the drawings and models. Therefore, information on Dimension and Geometry which is ranked quite important by the property managers is rarely spot on. One possibility to meet this inefficient and costly workflow, based on majority of interviewed BIM specialists is use of laser scanning technology which is elaborated in the improvement section.

5.3.2 Information distribution

Whyte et al. (2016b) put forward one of inherent challenges of information distribution in the AEC industry. They state that there is no temporal overlap between the group completes their activities and disengages, handing the information over to another group that engages to conduct related but different activities. However, this might not be a substantial challenge if the as-built information is in the format that the recipient of the information could extract its requirements and satisfy its information needs. Yet, based on the empirical data this has not been the case with current information delivery. For instance, facility managers usually contact the construction firms and ask where they can locate the information that they are seeking. Chart 4.1 already showed that the information delivery does not satisfy the FM practices in most cases which one explanation might be that information is not transferred sufficiently.

Another issue is that currently information is transferred in only one way which is from upstream to downstream, designers to constructors and afterwards to the FM. Bryde et al. (2013) refer to the fragmented nature of the construction industry, which inhibits knowledge obtained in a project to be utilized in the next projects. Therefore, there is no loop of information to use lesson learnt from the past projects in the new projects (Becerik-Gerber et al., 2012) and connect the data to form new knowledge and insights (Whyte et al., 2016a). Nonetheless, based on the interviews this issue is rather underrated by the participants which could be rather thought provocative.

5.3.3 Information interpretation

The as-built information is intended to be available, retrievable, and audited (Whyte et al., 2016b) to be verified for consistency of the information. Yet achieving these features have remained a challenge (Çıdık et al., 2017). The results from the interviews provide evidence on the fact that all three features are to some extent missing with current deliveries. Property managers state that sometimes construction managers do not hand over all the required information and construction managers blame the property managers in return and believe all the requested information in the specifications is provided to the property owners. By and large, the AEC industry is attributed with fragmented use of information and lack of a shared understanding amongst all different actors (Bosch-Sijtsema, 2014; Bosch-Sijtsema & Henriksson, 2014) and the problems mentioned above are just explicit examples of this. Nevertheless, not sufficiently available and retrievable format of as-built information inhibits complete understanding and common interpretation over different information elements which leads to ineffective use of information. Also, authentication and verification of the information provided in the documents with current situation of delivery is debatable. Property owners admit that the as-built information verification is not accomplished effectively which substantially affect the issue of trust toward to received documents. As Hardin and McCool (2015) state the attitude toward as-built information in the time of delivery is the ‘’Check the box’’ to hand over the project without scrutinized information verification due to inefficient workflow this task currently possesses.

5.3.4 Organizational memory

Before moving to the discussion over the organizational memory, it might be worthwhile to remind why at the first place as-built information matters. As elaborated in the theoretical chapter, property owners demand the as-built information for efficient and effective (Behzadan et al., 2016; Whyte et al., 2016a), sustainable and safe performance of their facilities (Hardin & McCool, 2015). Myriad ranges of valuable information produced in preceding stages needs to be stored in an organized way to manage this information efficiently (Whyte et al., 2016b). In this context, based on the interviews, deliveries which are received in PDFs and DWG file formats are stored in the databases within facility management systems. These facility management systems function as organizational memory which are developed to store the essential information and provide smooth access to be readily retrieved. Existing facility management systems prevent information loss, perform some data analysis and store the information in a retrievable format. Based on the interviews with property managers, these systems function sufficiently regarding storing and providing information for corrective, predictive and preventive maintenance management. While Becerik-Gerber et al. (2012) remark that current facility management systems lack visualization feature which could hinder optimized space management and efficient locating building's component, surprisingly, property managers believe accessing the representation of all spaces and where all the components are located is not of a significant value for them. However, they acknowledge that the problematic point is the data stored through them is not interoperable to other facility management systems and design software. Then it could be argued that these systems work effectively but in isolation. According to the interviews, overtime, considerable amount of data has been stored within these systems. Currently, there is no direct interconnection between these facility management systems which if there was, it could result in creation of new information and perhaps new value. According to one property manager this knowledge creation could be for instance on economic and environmental analysis. Also, this interoperability constraint inhibits creation a fully closed loop between design, construction, and FM operations data in which new knowledge and information could be generated. Considering all, it should be noted that large property owner companies already have enormous number of facilities and therefore large amount of data stored on these databases. According to Becerik-Gerber et al. (2012) any possible alternative to these systems without evidence on successful real-world cases would be resisted by the clients since that would need investment and a possible organizational change.

5.4 BIM-supported as-built information delivery

This section follows the same structure as the prior section. The purpose behind following the same structure of four organizational learning's constructs is evaluating how the mentioned challenges could be improved with BIM-supported as-built information delivery in a more scrutinized manner.

5.4.1 Information collection

As already explained, the starting point and main prerequisite of collecting operational and maintenance information, as Whyte et al. (2016b) claim, is to specify which information is required to be collected and how this information should be structured at the start of the project. The interviewed construction and design managers state that the greatest challenge with the information collection is that most often the clients do not know what information they need. Nonetheless, Whyte et al., (2016b) explain this would be a quite challenging task to specify data requirements for operation and maintenance of the facilities at the beginning of the project. Interestingly, the research by Çıdık et al. (2017) proves that in case Building Information Models are supposed to be used as the media for as-built information delivery, the Asset Information Matrix (AIM) should be specified by the client or their consultant. AIM defines the parameters for models, which object should be included, which information should be incorporated and how the data should be structured and coordinated (McPartland, 2017). As described in previous chapter, one possibility to meet this challenge would be that the client hires a consultant to benchmark what information will be needed for FM phase and inform the contractor how this data should be captured and structured as the BIM strategist G is currently working in a project to perform this task. The conclusion of this section is underpinned by Kassem et al. (2015) and Teicholz (2013) who remark property managers should prioritize and detail their information requirements. They believe although Building Information Models delivered at the close out of the project could be considered an enriched resource for FM, not all the data is functional within FM daily practices. Overall, by confronting literature with empirical data, it concludes that BIM provide an organized framework to collect the required information and structure it to be readily retrieved especially when facility managers need to locate the information on the building’s component. BIM could potentially enhance workflow of information collection within a project which was previously known as an ineffective errand. The Previous explanations on the use of laser scanning express that BIM provide the efficient structure with an effective timely and costly manner. Laser scanning provides reliable and accurate as-built information on Dimension and Geometry which currently collecting accurate data is both labor and cost intensive. Overall, with current ineffective workflow, utilization of laser scanning could be recognized as one of the justifications to implement BIM as-built information delivery instead of using artifacts delivery.

5.4.2 Information distribution

As brought up throughout this study, The AEC industry is attributed with its project-based nature (Azhar, 2011; Bosch-Sijtsema, 2014) with almost no temporal overlap between the group completes their activities and disengages (Whyte et al., 2016b) which in this context are contractors, handing the information over to another group that engages to conduct related but different activities (Whyte et al., 2016b). Research by Whyte et al. (2016b) depicts the mentioned issue as having a negative impact on the information delivery. That being said, in the interviews, it was brought up that BIM could be adapted to satisfy the information need of different actors. By adaptation here is meant that by delivering BIM as-built information what is known as fragmented nature of the industry might not be an issue in this specific context. In fact, if delivered information is in a format that facility managers are needless to contact the preceding actors to interpret the information they are seeking, then it could be said that the information is distributed in an effective manner.

5.4.3 Information interpretation

Based on the interviews, the preliminary reason to utilize BIM as the media for as-built information delivery is that BIM provide a structured process to create planned information delivery. BIM as a coordinated and computable information management tool (Eynon, 2016; Lee et al., 2015) provide an organized way to deliver required information (Çıdık et al., 2017; Whyte et al., 2016a). By defining the parameters for the models, to determine the objects that should be included, and the information should be incorporated and the way the data should be structured and coordinated (Çıdık et al., 2017), the availability, retrievability, and auditability (Whyte et al., 2016b) in regard to the information deliveries which were previously known as a challenge would be resolved. Back to the empirical data, this would be one of the most important and explicit factors where utilization of BIM could bring value for the property owners and facility managers. Benefits of providing the facility data in one single resource in which the stored information could be merely retrieved is already undisguised. Also, information verification with BIM-supported as-built information delivery could be more effective. Here also it is notable to consider laser scanning which could directly capture the accurate data on geometry and dimension and create the foundation to attach other types of required information. Hence, this results in creating a trust toward the gathered information among all the involved actors.

5.4.4 **Organizational memory**

From the interviews, it was found that all three property owner companies were already using their own facility management systems to store and retrieve the information they need. They believe that their facility management systems were working effectively and meeting their requirement of everyday practices. However, as brought up in previous sections, the research by Kassem et al. (2015) and Shalabi and Turkan (2017) describe that the issue with facility management systems is that data stored through them is not interoperable to the other facility management systems and software used during design and construction phases. Building Information Modelling is regarded as an effective solution to settle interoperability problems (Lee et al., 2014) with Providing a schema that integrates FM data in a non-propriety format (Shalabi & Turkan, 2017). Shalabi and Turkan (2017) consider BIM as an alternative to store the FM information and be used as the media for organizational memory.

In fact, the paramount reason to use BIM as organizational memory is by using the historical BIM data across different buildings, the lessons that are learnt from the past and stored in BIM can be used to shape the design and construction of new buildings and foresee and reduce risks (Becerik-Gerber et al., 2012). Based on the interviews with BIM specialists, BIM could be used as an information management tool to assess the facilities operational performance, connect the data and make a comparison between those performances and make a more informed decision making on different FM issues. Also, as Becerik-Gerber et al., (2012) state, during design of the new buildings, the architects, structural engineers and MEP engineers would be able to control the maintainability of their design and optimize it to minimize life cycle cost of the facility throughout its lifespan.

Having said that, interviewed property managers recognize the flaws with this proposal. They state that they have numerous facilities which many of them are rather old and the data associated with them is stored in their facility management systems. They argue that they cannot take the risk to have the information in multiple formats and different standards and that is why even when receiving the as-built information in Revit or IFC files they transfer the data to their facility management systems. Interestingly, BIM specialists from the interviews argue that laser scanning can provide the baseline for BIM as-built information for the already constructed facilities in a time and cost-efficient manner. Thus, if a property owner company has numerous facilities and has the ambition to attain the data in non-proprietary format, BIM could enable achieving this by deploying laser scanning. Nevertheless, another shortcoming with BIM as the organizational memory is that working with its software demand rather high technical competence which currently facility managers do not possess. Therefore, in cases BIM is going to be used as the media for repository of facility data, the facility manager needs to acquire education which might not be financially feasible for all types of the construction project. Anyhow, as one of the BIM specialists claims, in case property owners going to adopt a life-cycle attitude then FM should adapt to BIM and BIM should adapt to FM. What is meant here is the idea that, if property owners do not have their information needs to perform their practices and activities satisfied which is presented in the chart

4.1 (i.e. space management, building maintenance management, controlling design maintability) then it could make sense for them to consider developing their current disposition against BIM. On the other hand, perhaps BIM could be ameliorated to be more tailored and suited to specific needs of facility management. Which one of them might be organizational memory should have a user-friendly interface which facility managers could make readily use. Current BIM-supported products are rather complex and do not provide the users with a friendly interface. As a result, the information cannot be updated easily. Yet, it could be argued that a 3D user-friendly software which provides updated and accurate information which locating required information in the building components could encourage property owners to consider using the new technology in their FM practices.

6 Conclusion and recommendation

Throughout this master thesis, it has been strived to understand and explore the importance of delivering the information needed for the operational and maintenance practices to the FM stage. Therefore, an inductive research strategy was adopted to investigate the current delivery of as-built information to the FM stage. The gathered data then was confronted with the literature to enable analysing the current delivery, its challenges and how BIM could be utilized to improve the information delivery. This last chapter is divided into three sections. The first section presents the concluding points answering the four research questions in an explicit manner. The second section consists of possible recommendation for the improvements realized by the authors and lastly to finalize the master thesis future research subjects which worth being conducted are mentioned.

6.1 Answer of research questions

What is the current practice of as-built information delivery in the Swedish AEC industry?

This master thesis firmly confirms the necessity of delivering accurate and complete as-built information and its significant role to perform FM practices which has been emphasized by the literature. Whereas, fragmented, temporal and project-based features of the construction industry have been negatively impacting a flawless information delivery, based on our data analysis, Swedish AEC industry is reflecting a growing awareness on the importance of as-built information as a valuable document. However, although many property owners appear to be concerned with the essence of as-built information and state that the quality of received as-built information is not satisfactory, still not adequate effort is dedicated to meet the deficiencies. Overall, there seems a rather insufficiently formulated request for the delivered information from the property owners to the contractors which might be due to lack of a solid knowledge to specify the required information for the operation and maintenance instructions.

What are the required information, connected to FM-processes, that should be included in as-built information for these to create value?

The most essential information types in terms of value are Function description of the building's components, Dimension, Geometry, Information on the building energy performance, Warranties, Material type, Design life, and Administrative cost information, respectively. Although all of the above types of information must exist in the as-built information document, it should be noticed that importance of the last two was understood lowest with the first four categories marginally leading. As literature strongly recommends, it should not be overlooked the fact that information is lifeblood of facility management practices and its correctness and accuracy impacts managerial decision making, effective corrective, preventive, and predictive maintenance management, and safe and sustainable operational performance.

What are the challenges with current methods of delivering as-built information?

With current as-built information delivery, there exist a few challenges and deficiencies. The very initial challenge is that the operational and maintenance information is not suitably specified at the start of the project. In most cases information specification is done quite generically which leads to second challenge which is information overload. However, Perhaps, the most visible issue is that the delivered information is not audited, retrievable, and accessible. These defects originate from the current method and format how information is collected and distributed which highly affects how information is interpreted and used by facility managers. In addition to ineffective information collection workflow, next challenge is update of the as-built information which is not efficiently possible with current delivery method. By and large, it could be resulted that quality of as-built information delivery is not satisfactory in most cases which deprives FM practices such as building energy management, space management and controlling design maintability to achieve the highest performance and efficacy.

How could BIM-supported information delivery improve the as-built information delivery and meet the challenges in the Swedish AEC industry?

This study reaches to the conclusion that some literature was already suggesting which Building Information Modelling could be used as the media for as-built information delivery. First and foremost, BIM provide the planned information delivery with the objects needed to be included in the models could be determined, the information required for FM stage to be attached to those objects could be incorporated, and the structure of data in models could be formulated. Therefore, well planned, practiced and orchestrated information collection and delivery which was desired by the literature could be obtained which could resolve the mentioned availability, retrievability, and auditability challenges. Furthermore, application of BIM for organizational memory is rather less straightforward. The issue is updating this information when changes occur, and it was understood that the Revit or IFC files are not created for being incrementally changed. However, it was suggested that the update could be carried out in the intervals. The importance of the information for the facility manager impact the frequency of those intervals, however, creating the models with current BIM technology is described as time and cost effective. Consequently, the key would be to attain the information in a non-proprietary format since it contributes to analyzing the historical BIM data across different buildings, using the lessons that are learnt from the past and stored in BIM in the design and construction of new buildings, and making more informed decisions on different FM issues. Obtaining the data in non-proprietary format would be a step forward to use BIM as a knowledge management tool to create a loop of information from the FM stage to the design and construction stages.

6.2 Recommendation

The very first recommendation to utilize BIM as the media for information delivery is to use expert knowledge to specify the required operational and maintenance information. From the empirical data it was known that when specifying which information is needed for operation and maintenance practices distinct aspects are needed to be realized. These aspects are legislation, current FM practice and the future needs of the client. Therefore, in a new construction project or in a refurbishment project a FM specialist could be assigned to perform the task on behalf of client. In cases which the FM specialist is also a BIM specialist the resulted benefits are considerably increased since this expert could define an AIM to specify which objects should be included to the models, how the data should be structured in the models, what information should be collected and incorporated to the model and suggest how the data should be controlled for accuracy and maintenance.

Also, defining a baseline and level of required operational and maintenance information which could be readily scaled up or down based on the type and specific needs of the facility could be a noteworthy idea. BIM could enable the platform and prerequisites to achieve this information specification method which could prevent further investments in the planning phase of every project.

And consequently, this study would like to emphasize the notion of utilizing BIM as a knowledge management tool. Throughout this study, the advantages of creating a loop of information between different stages of a facility's life cycle ware elaborated. Nonetheless, currently the data stored in the facility management systems are not deployed to inspect the lesson learnt from the past, assess the facilities operational performance, connect the data and make a comparison between those performances and make a more informed decision making on different FM issues. Altering the data storage to the non-proprietary format would worth being considered as an enabler to achieve mentioned eminences, optimization in space and energy management and controlling maintability of the design in the construction of new buildings.

6.3 Suggestion for further research

Firstly, one research study could be focused on the changes in behavior, routines, and processes that are needed to happen within the FM in order to be able to gain benefits from the BIM methodology.

Also, as brought up in the discussion chapter, some facility managers would prefer to use a user-friendly software to manage their required information when carrying out their everyday practices. A possible research study would be the features this potential software could provide to better correspond to FM requirements.

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8 Appendix

8.1 Appendix 1. Interview participants

Construction

The roles that are included in the construction category are construction manager and design manager.

A
Construction manager A explain the job as quite broad with the main responsibilities of keeping the project time table and the project floating. A lot of contract work and follow up additional cost that must be discussed and technical problem that must be solved was mentioned within the scope of work. Construction manager A also expressed that the responsibility to delivery as-built information is within the scope. The most current project is in the production phase and the contract form used is design and build. The client is a residential development company, which they have experience collaborating with.

B
Construction manager B described the organizational chart of the current project as consisting of three main subsets, where the responsibility of the construction manager B is a safe, smooth, and efficient production.

C
Design manager C is active in the design and construction phase in which he is responsible to lead the design team consisting of architects, structural engineers, fire specialists, BIM specialists, MEP engineers etc.

4.1.2 FM

D
Facility manager D has an overall responsibility to manage the maintenance of the buildings and the personal working within a district in the east of Gothenburg with approximately 3600 apartments. The role of facility manager D in the projects is to put the demands or specifications for the house. He is involved in the early stages of the project and when they are taking over the buildings, generally not in the time between. The relation to as-built information comes mainly from the production of new buildings, because of poor quality in the as-built information in the older buildings, and since most of the building that are being maintained by facility manager D is old, there is a limited use of as-built information.

E
Facility manager E has an overall role of the care and maintenance unit, that includes eleven hospitals and 110 employees. The focus of his job is to manage the corrective, preventive and predictive maintenance of the hospital’s facility. Facility manager E is active in the facility management phase of the projects yet limited involvement in the start of the project and the handover of the project.

F
Facility manager F is a project developer in a large real estate company in Gothenburg. He is involved in all the projects within the company in Gothenburg both in new construction projects and refurbishments. He is involved in all the phases in the project.

4.1.3 BIM

G
The work of BIM strategist G is described as, looking at how data should be structured, where the focus entails looking at the project planning phase and writing strategy documents and coming up with the best solution and strategic approach for the project. Where the most recent project has been for a commercial property company, in a refurbishment project.

H
BIM specialist H is currently working as BIM coordinator currently working at one of the phases of the 74-floor skyscraper in Gothenburg. His role is to guarantee that the delivery from the different disciplines are correct based on the project's specifications.

8.2 Appendix 2. Interview guide for the FM actors

General
In order to understand the context of the projects you are active in some general questions have been formulated.

1.Can you describe your work and what your job entails?
2.What is your most recent project? Which phases of the project are you active in?
3.Who are the actors you are collaborating with in these projects?

As-built information
The core of this research is built upon the as-built documentation and the information included in the handover between construction and operation, questions have been formulated in order to get a better understanding of the process.

1.What is the request policy regarding as-built information within your firm?
2.What documents do you receive during the handover of as-built information? (For instance: Submittals, specifications, changes, RFIs, record documents)?
3.What information do you specify to be included in the process of handing over as-built information? Let's say a Wall (Element specifications such as dimension, geometry, material type, design life, warranties, installations (filters, plumbing fixtures, etc.), other notes)
4.How do you describe the quality of as-built information?
5.What is the format of information which is provided to you?
    -Which format of information delivering is more desirable for you? Why?
6.How do you know the information you receive is verified?
7.To what extent are the received as-built information able to be updated?

-Do they have the ability to be updated throughout the life cycle of a facility? After you receive the as-builts?

-Who is responsible to update the changes? BIM consultants? Facility managers? In-house designers? (Changes occurs in element specifications such as dimension, geometry, material type, design life, warranties)

8.What are the challenges for the people who are not part of the delivery team to interpret this information?

9. What would be needed in the documents in order to be able to use them?

BIM

The technological opportunity that is provided by BIM is suggested to enable dynamic as-built documentation.

1.Do you use BIM in your work? How do you use it? Do facility managers work with BIM software?

-What sort of collaboration from other actors is needed to make the most of BIM?

2.What are the drivers and challenges for your firm to use BIM?

3.Is there any CAFM (Computer Aided Facility Management) that you use to manage your operating activities?

8.3 Appendix 3. Interview guide for the construction actors

General

In order to understand the context of the projects you are active in some general questions have been formulated.

1.Can you describe your work and what your job entails?

2.What is your most recent project? Which phases of the project are you active in?

As-built information

The core of this research is built upon the as-built documentation and the information included in the handover between construction and operation, questions have been formulated in order to get a better understanding of the process.

1.What is the delivery policy regarding as-built information within your company?

2.What documents is included in the process of handing over as-built information? (Submittals, specifications, changes, RFIs, record documents)?

3.What information is specified to be included in the process of handing over as-built information by the client or property owner? Let’s say a Wall (Element specifications such as dimension, geometry, material type, design life, warranties, installations (filters, plumbing fixtures, etc.), other notes)

4.What is the format of information which is provided to other actors? Why is this format chosen?

-What is your strategy toward delivering as-built information? Artifacts (2D static data) such as PDF files or constants deliverables which could be easily updated such as BIM-formatted information?

5.How do you describe the quality of as-built information?

5.How do you know the information you provide is verified?

6.To what extent are the as-built information able to be updated?

-Do they have the ability to be updated throughout the life cycle of a facility?

-Who is responsible to update the changes? In house designers architects? (Changes occurs in element specifications such as dimension, geometry, material type, design life, warranties)

-What is your framework to integrate changes to the design information?

7.What is the technology you use to deliver as-builts? (BIM software, laser scanning)

8.What are the challenges for you in handing over the information when next actors have problem interpreting this information?

9.Is there any information that is missing in the as-built documentation?

BIM

The technological opportunity that is provided by BIM is suggested to enable dynamic as-built documentation.

1.How do you use BIM in your project delivery?

-What sort of collaboration from other actors is needed to make the most of BIM?

2.What are the drivers and challenges for your firm to use BIM?

8.4 Appendix 4. Interview guide for the BIM actors

General

In order to understand the context of the projects you are active in some general questions have been formulated.

1. Can you describe your work and what your job entails?
2. What is your most recent project? Which phases of the project are you active in?
3. Who are the actors you are collaborating with in these projects?

As-built information

The core of this research is built upon the as-built documentation and the information included in the handover between construction and operation, questions have been formulated in order to get a better understanding of the process.

1. Are you currently engaged in any projects where as-built documentation is specified as an objective within your work?
2. How is that task specified?
3. What is your relation to as-build documentation?
4. What are the challenges in terms of integration of data from as-design configuration baseline to the as-built configuration?

Required information

The aim is to find out valuable information in the FM stage.

BIM

The technological opportunity that is provided by BIM is suggested to enable dynamic as-built documentation.

1. How can BIM be implemented as the media to transfer information across the life cycle? (A media which goes from the design to construction phase and then passed to the facility management stage for the maintenance and operations activities)?
2. What are the steps and requirements to implement BIM as the media for information transfer?
3. What values could be attained to use BIM as the media for information transfer from the construction stage to facility management stage?
4. What does as-built documentation include when implementing BIM to deliver as-built documentation? What would be the documents? (architect model, structural model, MEP model?) How should these models include operational and maintenance information?
5. How does heterogeneous use of software impact information transfer and delivery?
6. What are the challenges when changing a component in the model? (For instance, when you want to update the model at FM stage)
7. What is the standard to determine the LoD in swedish market and which level of detail is tailored to produce operational and maintenance information? Could you tell us the different LoDs and for what purposes they are used to?
8. What additional efforts are needed to transfer a BIM to the operation stage of a facility and create a FIM, what are the main differences between BIM and FIM?
9. How should the ownership of the BIM be determined, and are the information included in the model the responsibility of the owner? How should responsibilities be specified between the involved actors?
10. Why is COBie created in relation to BIM process and how it benefits the interoperability problem?
11. Which sort of project suits implementing COBie and how can it benefit facility management? Which COBie data drop is needed for operation and maintenance practices?
12. What is the swedish construction industry disposition against implementing COBie and why?

8.5 Appendix 5. Questionnaire to the FM actors

8.5.1 FM practices

1. Please Grade the following practices or activities in terms of importance within your firm from 0 to 5? (0 is the lowest and 5 is the highest and it is possible to grade all of them the maximum or minimum)

-Domestic services (managing and planning the cleaning and janitorial services, security and waste)
-Building maintenance management and repair (Reflection concerning to trouble calls (i.e., a room is too cold, or pipe is leaking))
-Monitoring and optimizing the energy performance
-Checking maintainability (Maintainability is defined as the ability to achieve optimum performance throughout the lifespan of a facility with a minimum life cycle cost)
-Strategic FM (long-term development of the common infrastructure, and development of the facilities)
-Space management
-Locating building components
-Other (Please mention the activities)

2. Please Grade the following practices or activities which need to receive high quality as-built information for an effective performance from 0 to 5? (0 is the lowest and 5 is the highest and it is possible to grade all of them the maximum or minimum)

-Domestic services (managing and planning the cleaning and janitorial services, security and waste)
-Building maintenance management and repair (Reflection concerning to trouble calls (i.e., a room is too cold, or pipe is leaking))
-Monitoring and optimizing the energy performance
-Checking maintainability (Maintainability is defined as the ability to achieve optimum performance throughout the lifespan of a facility with a minimum life cycle cost)
-Strategic FM (long-term development of the common infrastructure, and development of the facilities)
-Space management
-Locating building components
-Other (Please mention the activities)

3. Please Grade the following practices or activities which do not have their information needs satisfied based on the current as-built information delivery? (0 is currently not at all satisfied and 5 is currently satisfied)

-Domestic services (managing and planning the cleaning and janitorial services, security and waste)
-Building maintenance management and repair (Reflection concerning to trouble calls (i.e., a room is too cold, or pipe is leaking))
-Monitoring and optimizing the energy performance
-Checking maintainability (Maintainability is defined as the ability to achieve optimum performance throughout the lifespan of a facility with a minimum life cycle cost)
-Strategic FM (long-term development of the common infrastructure, and development of the facilities)
-Space management
-Locating building components
-Other (Please mention the activities)

8.5.2 Required information

The aim is to find out valuable information in the FM stage.

1.Which of the following types of information are more critical in the time of refurbishment? (Grade from 0 to 5 and 0 is the least critical and 5 is the most critical)
-Dimension
-Geometry
-Material type
-Design life
-Warranties
-Information on the building energy performance (i.e. HVAC and lighting equipment)
-Function description of the functional components (i.e. MEP requirements)
-Administrative cost (building tax, authority fees, and property Insurance)
-Other (Please mention the information)

2.Which of the following types of information are more critical in the time of maintenance and repair of equipment (for example reflection concerning to trouble calls (i.e., a room is too cold, or pipe is leaking)? (Grade from 0 to 5 and 0 is the least critical and 5 is the most critical)
-Dimension
-Geometry
-Material type
-Design life
-Warranties
-Information on the building energy performance (i.e. HVAC and lighting equipment)
-Function description of the functional components (i.e. MEP requirements)
-Administrative cost (building tax, authority fees, and property Insurance)
-Other (Please mention the information)

3.-Which of the following types of information is more frequently needed within your everyday basis? (Grade from 0 to 5 and 0 is the least critical and 5 is the most critical)
-Dimension
-Geometry
-Material type
-Design life
-Warranties
-Information on the building energy performance (i.e. HVAC and lighting equipment)
-Function description of the functional components (i.e. MEP requirements)
-Administrative cost (building tax, authority fees, and property Insurance)
-Other (Please mention the information)

4. What sort of information do you provide to your users? (sustainable performance, energy usage, etc.)

	Dimension	Geometry	Material type	Design life	Warranties	Information on the building energy performance	Function description of the building's components	Administrative cost
Property manager D	5	4.25	4	2.5	0.5	2.5	4	4
Property manager E	3	3	3	.75	4.3	4.7	4	3.5
Property manager F	4.3	4.3	5	4	5	4.5	5	2.25
BIM strategist G	4	4	3	2	3.5	3.5	5	2.5

Total	4.15	4	3.75	2.3	3.85	4	4.5	2.75

	Domestic services	Building maintenance management and repair	Monitoring and optimizing the energy performance	Checking maintability	Strategic FM	Space manageme nt	Locating building components
Property manager D	3	5	5	4	2	5	3
	3	5	4	4	3	4	3
Property manager E							
Property manager F							
BIM strategist G	3	4	5	4	4	4	4
	3	1	3	0	3	2	3
Total	3	5	5	4	3	4.5	3.5
	3	3	3.5	2	3	3	3.5

- The upper row shows the grade of level of requirement to get high-quality information from Zero to 5 and the below row shows the grade of information satisfaction with the current as-built information delivery from Zero to 5