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Research on Barriers with BIM Implementation in Facilities Management

An interview study to investigate the main challenges and prospects of BIM in FM

Master's thesis in Design and Construction Project Management

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MASTER'S THESIS ACEX30

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ABSTRACT

This study investigates the underlying barriers to implementing BIM in facilities management by directly interviewing FM practitioners and consultants by obtaining their perspectives on this challenge in order to get a better understanding of the underlying causes of BIM's slow adoption in FM. Since this thesis is trying to describe a phenomenon in context, the qualitative research approach was chosen since the data gathered will not be numerical. The results of this study show that there are some differences in understanding of BIM in FM and that the construction industry has a vague perception of what type of information is vital to FM. The results also indicate that the main challenges with BIM integration in FM is information requirement and data-up-to date, with knowledge gap and information quality as the second most common barriers.

To summarise the findings of this study, it was discovered that BIM execution and information management were the most commonly encountered challenges in BIM integration, followed by technological challenges. The root causes of the challenges of BIM execution and information management are information requirements and keeping the model up to date, which leads to a need for delegation of responsibility and the creation of new roles. Additionally, the root causes of technological challenges appear to be an excess of BIM softwares, the use of proprietary formats in the AEC industry, and the legacy of old FM systems.

Key words: BIM, Facilities Management, BIM in FM, Challenges, Prospects

Forskning om hinder för BIM implementering inom fastighetsförvaltning

En intervjustudie för att undersöka de huvudsakliga utmaningarna och framtidsutsikterna för BIM i FM

Examensarbete inom masterprogrammet Design and Construction Project Management

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SAMMANFATTNING

Denna studie undersöker de underliggande hindren för att implementera BIM i förvaltningsskedet genom att direkt intervjua personer som antingen arbetar med förvaltning eller som konsulterar. Detta för att få deras perspektiv på de huvudsakliga utmaningarna och en bättre förståelse för de bakomliggande orsakerna till den långsamma adoptionen av BIM i förvaltningsskedet. Eftersom denna avhandling försöker beskriva ett fenomen i sitt sammanhang, valdes den kvalitativa forskningsansatsen eftersom den insamlade informationen inte kommer att vara numerisk. Resultaten av denna studie visar att det finns vissa skillnader i förståelsen av BIM inom fastighetsförvaltning och att byggbranschen generellt har en vag uppfattning om vilken typ av information som är viktig för fastighetsförvaltning. Resultaten indikerar också att de största utmaningarna med BIM-integrering i förvaltningsskedet är informationsbehov och datauppdatering, med kunskapsluckor och informationskvalitet som de näst vanligaste hindren.

För att sammanfatta resultaten av denna studie upptäcktes att BIM-utförande och informationshantering var de vanligaste generella utmaningarna i BIM-integration, följt av tekniska utmaningar. Grundorsaken till hinder kopplade till BIM-exekvering och informationshantering är informationskrav och hålla modellen uppdaterad, vilket leder till ett behov av ansvarsdelegering och skapande av nya arbetsroller i förvaltningen. Grundorsakerna till tekniska utmaningar verkar vara ett överflöd av BIM-programvara, användandet av proprietära format för BIM och traditionella fastighetsförvaltningssystem.

Nyckelord: BIM, Fastighetsförvaltning, BIM i Fastighetsförvaltning, hinder, framtidsutsikter

Contents

Preface

This thesis has been conducted at the Department of Architecture and Civil Engineering, Division of Construction Management, at the Chalmers University of Technology, Gothenburg, Sweden. A representative from Ramboll Sweden AB was partly responsible for the inspiration and concept for this master thesis and provided guidance throughout the study. We would especially like to thank:

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Gothenburg, June 2022
Benny Quach & Oscar Wenström

Notations

ACE – Architecture, Construction and Engineering

AI – Artificial Intelligence

AIM – Asset Information Model

API – Application Programming Interface

BAS – Building Automation Systems

BEMS – Building Energy Management System

BEP – BIM Execution Plan

BIM – Building information Modeling

CAD – Computer-Aided Design

CAFM – Computer-Aided Facility Management

CIRP – The International Academy for Production Engineering

CMMS – Computerized Maintenance Management System

COBie – Construction Operations Building Information Exchange

ESG – Environmental, Social, and corporate Governance

FIM – Facility Information Model

Fi2xml – A Swedish standard that handles and communicates property information

FM – Facilities Management

GIS – Geographic Information System

HVAC – Heating, Ventilation, And Air Conditioning

ICT – Information and Communications Technology

IFC – Industry Foundation Classes

IoT – Internet of Things

LOD – Level of Development

MVD – Model View Definitions

O&M – Operations and Maintenance

PDF – Portable Document Format

XML – Extensible Markup Language

1 Introduction

The operational phase has the highest spending output of the total cost of the building lifecycle and considering the construction cost of the building itself, is usually a minor fraction of the operational costs or the value of the activities performed during the operation and maintenance (O&M) of facilities (Aziz et al., 2016). Thus, it is critical for facilities management (FM) teams to have accurate, complete, and easy access to information and data related to the facilities in order to perform both effective and efficient O&M activities (Matarneh et al., 2019b). The problems which often occurs in the daily operations of FM, is related to issues regarding locating assets for maintenance, extracting information from 2D drawings and combining these with specifications and operational and maintenance manuals (Stride et al., 2019).

FM is thought to play a significant role in ensuring the effective operation of the built environment. According to Edirisinghe et al. (2017), FM is a profession that integrates people, place, process, and technology to ensure the functionality of the built environment. Furthermore, the goal of the FM process is to keep the asset operating condition close to the original condition as long as it attains cost-effectiveness during operation, boosts energy efficiency, supports sustainability, and improves facility quality (Haider & Koronios, 2013; Too, 2010).

Applying Building Information Modelling (BIM) in FM can reduce costs in the operational and maintenance phase (O&M), as well as facilitate value creation from its capability to be used as a unified platform including data and information needed for daily FM activities (Matarneh et al., 2019b). The data and information that are connected to a facility, can be stored, accessed, and exchanged by utilising BIM. FM can thus use BIM as a knowledge repository to document facility information and to support decision making process of FM managers during the O&M phase of the building (Aziz et al., 2016; Stride et al., 2019). Furthermore, Edirisinghe et al. (2017) argues that while the potential for leveraging BIM in facility operations is compelling, the use of BIM has lagged when compared to its use in design and construction.

There are several challenges and barriers to overcome when implementing BIM in FM according to the literature. Stride et al. (2019) states that as-built models that are created needs to be updated continuously when changes are made in reality. If not, this will result in an inaccurate model of the facility and obstruct the ability to locate building elements in the model reversing time and cost savings (Stride et al., 2019). Utilising BIM in FM is mainly associated with streamlining information flow between stakeholders during the lifecycle of the project and also to facilitate the handover process to FM. However, this flow of information is not automated and thus there are technical issues to solve such as improving interoperability between BIM and FM systems (Matarneh et al., 2019a). Current FM systems is, according to Matarneh et al. (2019a), lacking interoperability capabilities and thus results in poor data management and due to the to widespread use of different BIM and FM platforms, means that interoperability is one of the main challenges in successfully applying BIM in FM.

1.1 Purpose

This master thesis examines a possible implementation of BIM in the O&M phase of facilities. The focus of the topic is to investigate the most common aspects that inhibits FM companies to implement and utilise BIM in their operations.

1.2 Objective

The primary objective of this research is to investigate the underlying problems or hindrances of implementing BIM in FM by directly interviewing FM practitioners to get a better understanding of the underlying causes of BIM's slow adoption in FM. This thesis will also contribute to the existing knowledge gap of BIM in FM by addressing the possibilities and benefits of BIM as well as the impact it may have on the FM industry.

1.3 Research questions

This report aims to contribute to the understanding of the challenges in BIM implementation in FM by answering the three research questions listed below:

1. What are the most common challenges experienced by FM practitioners of BIM implementation in their work?
2. What is the root cause of these challenges?
3. How could the concept of BIM be further developed to fit the needs in FM?

1.4 Limitations

The overall objective of this report is to investigate the topic of BIM and its implementation in FM. The primary focus of this report will be on the main barriers and challenges for FM to implement BIM in their daily operations, specifically the challenges of applying BIM in the O&M phase. Interviews with the consultants will not be focused on the use of BIM in the design and construction phase, but solely on information handling and the handover process to the O&M phase. Furthermore, the interviews with FM companies will include companies that are currently implementing BIM in O&M and those that are not implementing BIM in O&M, categorised as implementing, interested and not currently interested.

1.5 Structure of the Thesis

The report begins with an introduction that provides background information on the researched topic. Afterwards, the BIM concept and FM are presented in a theoretical framework. The theoretical framework further includes the application of BIM in FM and its benefits. The last section includes the most common challenges to overcome in the BIM implementation in FM based on a literature review. The next part of the report is a methodology chapter. This chapter outlines how the study is conducted and what research methods will be employed to answer the underlying questions. Following that, the main findings of the interviews are presented, and the section is divided into consultants' and FM personnel's perspectives. Presented first are results regarding the digitalisation of information management, followed by an in-depth analysis of their perceptions of building information modelling and its applications in FM. A discussion chapter will be presented in which gathered data and information from theory and interview findings are compared and analysed. The concluding chapter summarises the research findings and provides answers to the question(s).

2 Theoretical framework

This chapter contains the theoretical framework, establishing the study's context and background. Firstly, the concept of BIM is introduced and defined. Secondly, FM is explained in terms of information and communications technologies. Third, the implementation of BIM in FM is described, followed by the possibilities that BIM in FM could imply by demonstrating the importance of BIM and its value in FM. Fourth, the challenges associated with BIM implementation in FM are defined, providing a more in-depth understanding of the barriers that prevent BIM implementation in FM.

2.1 Building Information Modelling

Building Information Modelling (BIM) is defined by Eastman et al. (2011) as a modelling technology and the associated set of processes for producing, communicating, and analysing building models using parametric digital databases. Eastman et al. (2011) further elaborate that the concept of parametric objects is critical for understanding the differentiation of BIM and traditional 3D objects. In their work, they defined parametric objects as an object with nonredundant integrated geometric and associated data and rules that can automatically modify associated geometries at different levels of aggregation. The ability to create building models comprised of parametric objects is what Eastman et al. (2011) consider as the essence of BIM. This technology can be used for visualisation, management of facilities, cost estimating, construction sequencing, and collision detection in spatial relationships.

According to Azhar et al. (2012), BIM has two terminologies that describe it as a technology and a process. From a technology standpoint, BIM is a simulation comprised of 3D model components linked to all necessary information related to project planning, design, construction, or operation (Azhar et al., 2012). When BIM is viewed from a process perspective, it is a virtual process that involves well-integrated and cooperative project teams that include designers, builders, owners, and other stakeholders in the life cycle of buildings or facilities in the development of a virtual model. The two pillars that make the BIM process successful, according to Azhar et al. (2012), is communication and collaboration, which necessitate effective communication, trust, transparency, information sharing, and shared risk and reward amongst the involved actors.

While BIM has grown in importance in the Architecture, Engineering and Construction (AEC) sector over the past decade and has been utilised extensively during the design and production phases of a building, the operational applications have been neglected (Carbonari et al., 2018). When implementing BIM in FM processes, the most challenging aspects involve updating design models with as-built information and ensuring that operational input is available during design and construction. Another challenge that FM faces is handovers from project deliverables, which means that once a building project is completed, the data handed over is frequently insufficient or inaccurate, with impractical use for FM purposes (Carbonari et al., 2018).

However, Carbonari et al. (2018) contend that while the aforementioned challenges appear to be most easily overcome for new buildings, the best outcomes and opportunities for improvement and attainment of efficiency gains come from using information models for existing building stock. Making informed decisions and better managing a building using more accurate and reliable information about the building would have a significant impact on the existing estate, with the benefits lasting throughout the building's life cycle or beyond in the case of refurbishment. The process of implementing accurate existing-building-information models, on the other hand, is even more difficult than obtaining accurate models for new buildings (Carbonari et al., 2018).

2.1.1 Building Information Management

According to some scholars, BIM could be referred to as either Building information Modelling or Building information Management (see Nyvlt, 2017; McArthur, 2015). In this thesis, BIM will refer to Building information modelling. Furthermore, Nyvlt (2017) suggests that by using Building Information Management models in terms of BIM, all decisions can be supported by collecting, sharing, and utilising data across all disciplines and Life Cycle phases. Using the definition of McArthur (2015), Building Information Management is not just a 3D Computer-Aided Design (CAD) tool, but a database that stores a number of attributes and relationships about a wide range of building elements. In addition to integrating design, analysis, cost estimating, and construction scheduling, Building Information Management models are transforming the way buildings are designed and constructed (McAarthur, 2015). As BIM extends into the post-occupancy period, it can be used to support FM and building operations, providing a consolidated view into all aspects of a building's operational performance.

Although Building Information Modelling is deeply rooted in technological advances and partially derived from other industries, it also involves social exchanges between organisational actors. As a result of technical and procedural innovations within the construction industry, Building Information Management has also widened to include O&M. Throughout the lifecycle of a constructed facility, Building Information Management comprises the generation, exchange, and management of data (Nyvlt & Pruskova, 2017).

2.1.2 Level of Development

In BIM, the Level of Development (LOD) protocol describes the basic guidelines for its use (Weygant, 2011). At any given time, LOD identifies the specific content requirements of BIM model elements. By identifying this information, insufficient information is reduced.

Using LOD, construction players in the AEC industry can precisely specify and articulate content with a high level of clarity and establish quality assurance for the 3D models throughout the project lifecycle. LOD is related to Level of Detail, where Level of Detail refers to how detailed the elements of a building model are (Weygant, 2011). Depending on the application, the Level of Detail describes how much detail is included in the building model components. Meanwhile, LOD refers to how deeply the element's geometry and information related to its components have been considered by the involved actors when designing the model. To put it simply, LOD refers to how much the project team can rely on the information provided by the model (Latiffi et al., 2015). The Level of Detail is an input to the element, whereas the LOD defines the output. As an example, LOD 100 in Figure 1 serves as an example of a building element that is highly detailed but not as developed due to a lack of information embedded in it.

In the design phase, LOD is used to address several issues. In order to avoid misinterpretation, it is imperative to be precise when modelling what is to be modelled. In addition, building model elements should be differentiated by the amount of information they require. With this application, model users can define the use of building models, while construction stakeholders can clearly understand the limitations of received building models (Latiffi et al., 2015). LOD can be divided into five levels, which are LOD 100, LOD 200, LOD 300, LOD 400, and LOD 500 (Ikerd et al., 2013). These levels cover conceptual and as-built aspects, as well as FM. In Figure 1, each LOD characteristic is summarised.

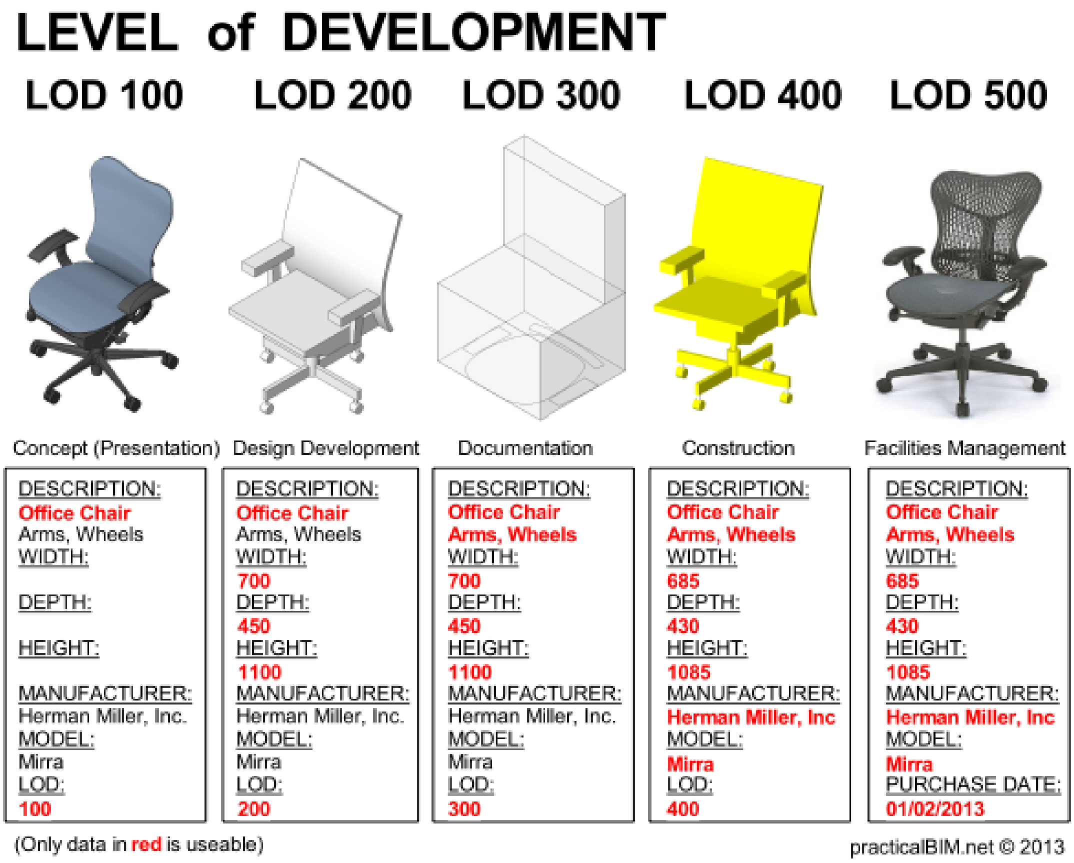

Figure 1. The level of Development (McPhee, 2013).

2.1.3 Industry Foundation Classes

Industry Foundation Classes (IFC) is an object-oriented file format and widely accepted openBIM standard that is developed and maintained by buildingSMART International and is the primary standard for data exchange. IFC provides necessary lifecycle information modelling and exchange protocols, in the form of a data schema and file format structure, to facilitate compatibility between software applications within the AEC and FM industry (Sadeghi, 2019).

IFC has been referred to as the Portable Document Format (PDF) of BIM, according to buildingSMART International (2018). Just like a PDF file, an IFC file is a frozen copy of the original content. For example, it can be viewed, measured, used for clash detection, cost estimation or simulation, and is not intended to be edited. It is, however, possible to edit an IFC file. Almost all software used in the construction industry that import IFC, treat the IFC model as a reference copy of the original design. Some tools allow minor edits to IFC model, such as an isolated activity that doesn't have any effect on the original design model. The IFC based workflow is meant for each discipline to remain author and owner of their model content (buildingSMART International, 2018).

2.2 Facilities Management

There are several definitions of Facilities Management that can be identified in the literature. One definition of FM is, according to Stride et al. (2020), "*the process of planning, managing, maintaining, rationalising and accounting for facilities and associated services, while simultaneously seeking to reduce the associated overall costs for a specified level of performance*" (p.1795). In this study, FM will be used in the context of describing the management of facilities in the post construction stage namely the operations and maintenance phase (O&M). Lewis et al. (2010) state that operations is including the necessary services that is needed for equipment and systems to keep it condition as designed or at the least level that is equal to the operational goals set by the FM team. Furthermore, maintenance includes services that help to restore equipment and systems to design conditions or sufficient conditions that can be compared to what is sufficient according to the project scope. Examples on equipment and building systems are heating, ventilation and air conditions systems (HVAC), building automation systems (BAS), and technologies for renewable energy and lighting. Also, software such as computerised maintenance management systems (CMMS) and computer aided facility management systems (CAFM) which is used to support these systems. In order for the O&M team to facilitate a high-performance building, a proactive management process is needed for optimal energy and maintenance operations (Lewis et al., 2010).

Heaton et al. (2019) state that the O&M cost of a construction project is often neglected by clients and stakeholders during the design and constructions stages, this despite the fact that the O&M phase stands for the largest part of the of the total life cycle cost of a building. Approximately 85% of the total cost is estimated to be associated with facility operations while 15% is associated with the development process (Wong et al., 2018). However, Stride et al. (2020) state that clients and stakeholders usually focus on the initial or early phase of the construction project, where the expenditure is high during a short period of time, as it affects the development proceeding forward. Due to the major investment during the O&M phase of the construction project, clients and owners should consider more focus on FM during this stage.

2.2.1 Facilities Management in Sweden

FM is an emerging market in Sweden and its industry value is estimated to be SEK 150 billion and close to SEK 400 billion in the Nordic region. FM is part of several disciplines involving buildings and workplaces and the concept is sometimes differentiating FM and Real Estate Management. However, in some cases the concepts are combined and thus both property management and internal soft service functions such as Asset Management (own the building), Building Management / Real Estate Management (manage and operate the building), Facilities Management (use the building) is used synonymously with FM (IFMA, 2016). In this study, FM is referred as incorporating all these areas.

2.2.2 Facilities Management Information

FM contains several multidisciplinary services to be able to maintain and enhance building assets (Matarneh et al., 2019c) and FM depends on robust information management to be able to perform successful building O&M tasks. According to Wijekoon et al. (2018), the information needed to complete FM operations can be divided into three categories, mainly, construction information, business information and facility operation information. The construction information includes information that is generated and used during the design and construction phase of the project, this includes asset information, space allocations and maintenance schedules. Business information, or so-called market-driven information, is mainly about having the right information at the right time to run the business and to keep a competitive advantage in the market. This includes functional requirements such as space being used, expected occupancy and other business functional information that relates to facility operations. The facility operational information is related to O&M of the facility in its current and future environment, and includes aspects such as energy consumption, maintenance records and information regarding facility operation staff (Wijekoon et al., 2018). Wong et al. (2018) further states that maintenance management and energy consumption are two major important areas of interest in daily operations in FM. Building maintenance specifically requires analysis and integration of information and knowledge that is generated from different stakeholders in the project such as maintenance records, work orders and cause and effect of failures.

2.2.3 Information and Communications Technologies

One of the challenges for the FM team is having access to accurate and comprehensive real-time information to perform their daily operations. Although there are several commercial systems that have been developed for FM to provide necessary information to support the decision-making process for operating and maintaining the building, Information and communications technologies (ICT) are used to provide solutions to these issues in FM practices. Two fundamental ICT systems used to increase profitability and quality in O&M are FM software tools such as CMMS and CAFM (Sulaiman et al., 2021). FM processes include data and information that are structured and managed in CMMS and CAFM and according to Wong et al. (2018), the primary purpose of these systems is to manage and record data used in daily maintenance operations such as asset and work order management, inventory control, and service request generation. CAFM also provides additional functions such as reactive and planned maintenance, space management and resource scheduling. Today, it is common practice to collect and enter the necessary data for CMMS and CAFM systems manually. Also, due to interoperability issues, the need for data changes throughout the project lifecycle, and the need for data to be manually entered several times in each of the individual FM systems, a process failure is likely (Matarneh et al., 2019a).

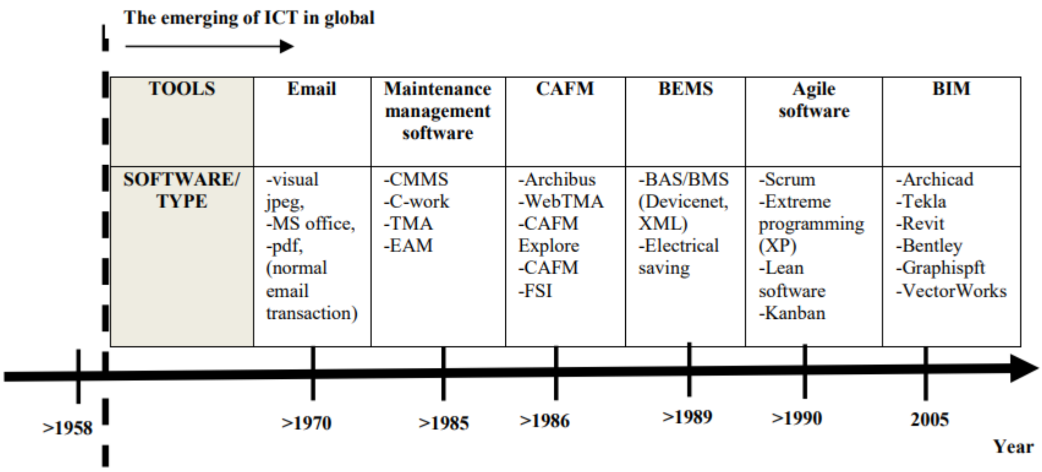

Figure 2. ICT evolution in FM for over 40 years (Aziz et al., 2016).

Moreover, technological improvements represent one of the greatest potentials for sustainable FM (Støre-Valen & Buser, 2018; Bröchner et al., 2018; Araszkiewicz, 2017). According to Støre-Valen & Buser (2018), as standardisation and digitisation progress, effective decision-making will be possible, and FM processes will be greatly enhanced. However, according to their study, the companies that participated in their research struggled with the integration of such technologies and appeared to find this process difficult. Furthermore, the authors claim that some participants were still fighting with the organisation over building documentation and a lack of follow-up on building changes, repairs, maintenance, and renovations.

As shown in figure 2, the emergence of ICT in FM has globally gone through several stages over the last decades, and as described by Bröchner et al. (2018), FM is about to enter a new era of digitalisation, with smart data solutions for planning, design, monitoring, control, and general management. It is further claimed that the availability of low-cost sensor technology will allow FM to use real-time condition monitoring, automated solutions, and data for key performance indicators of services and their coordination to expand its use in real-time condition monitoring and monitoring systems. According to Bröchner et al. (2018), FM can improve efficiency, flexibility, and service quality in the future by utilising big data solutions and robotics. Similarly, Araszkiewicz (2017) believes that the advancement of digital technology supporting FM, such as the Internet of Things (IoT), Big Data management systems, and advanced connectivity, will have a positive effect on the efficiency of FM managers and their clients. Furthermore, Araszkiewicz (2017) also state that the integration of BIM, GIS (Geographic Information Systems), and BEMS (Building Energy Management System) allows for a more intuitive and effective facility management, thus is a critical area for digital technology development in FM.

2.2.3.1 Digital Twin

Information based systems such as BIM allow for more effective AEC and FM operations while also increasing the efficiency and performance of building projects throughout their lifecycle. However, BIM is lacking the ability to provide complete solutions for automation in the AEC/FM industry alongside the ability to handle the revolution of intelligent data technologies and interoperability issues (Hosamo et al., 2022). Due to the emergence of a new era of digitalisation in the AEC/FM industry has resulted in smart solutions through the development of intelligent technologies such as promising digital technology platforms known as Digital Twins (Ozturk, 2021).

According to Hosamo et al. (2022), a definition of a Digital Twin from The International Academy for Production Engineering (CIRP) was released in 2019 which states: "*A Digital Twin is a digital representation of a unique active product (real device, object, machine, service, or intangible asset) or unique product-service system (a system consisting of a product and a related service) that comprises its selected characteristics, properties, conditions, and behaviours through models, information, and data within a single or even across multiple life cycle phases*." (p.2). Additionally, a Digital Twin can be described as a virtual replica of the environment of a physical building or asset and is a rather new concept in the AEC/FM industry (Ozturk, 2021). Furthermore, a Digital Twin could improve AEC/FM operations by dynamically integrating data and information though an asset lifecycle. This by providing a virtual information model which provides real time data synchronisation through IoT sensors, and in combination with machine learning and artificial intelligence (AI) integration, being able to coordinate and automate the physical asset or building during operational changes (Hosamo et al., 2022).

2.2.3.2 COBie and Fi2xml

Definitions of various subsets of so-called MVDs (Model View Definitions) have been developed to simplify the management of IFC files and Construction Operations Building Information Exchange (COBie) is the name of one of these definitions. COBie is a spreadsheet format that allows for the exchange of structured data for asset commissioning, operations, and maintenance (Wijekoon et al., 2018). According to Tu & Chang (2017), COBie is an international standard used for managed asset information delivery, such as providing building data to FM managers. They further explain that COBie has been recognised as an important standard in BIM, which is why many BIM software supports COBie and allows for the export of COBie worksheet data.

As IFC is used for communication between CAD software's, standards such as COBie are used for communication between people (as in data and information sharing from construction to O&M). IFC and COBie are thus standard data formats used for exchanging data between platforms, and utilising these standard formats, prevents data loss and thus facilitates information sharing, use and reuse of products and materials, and also improves coordination and communication (Ozturk, 2020).

As part of BIM Alliance Sweden, the Association for Management Information developed concepts and value lists (class lists) suitable for the Swedish adaptation of COBie. When requirements for value creation are required that cannot be met using IFC, Fi2xml can be used instead. Fi2xml is a common language (or interface) that allows information to be read from various databases. The information contained in various information systems, such as CAD, technical systems, finance, and administration, is transformed into XML language by the information platform, making the information readable in other systems (BIM Alliance Sweden, 2014).

2.2.4 Information handling in Facilities Management

Matarneh et al. (2019c) state that there is a general lack of understanding of what sort of information is needed for the FM team to use in the O&M phase and how to transfer this information effectively into existing FM systems, even though different methods and tools have been developed for information exchange during the lifecycle of the building.

When the extensive documentation of information required for effective facility O&M is considered, it is clear that finding efficient ways to collect, access, and update this information is critical (IFMA, 2013). Excessive time is spent locating and verifying specific facility and project information from previous activities. As-built drawings from both construction and maintenance procedures, for example, are not routinely provided, nor are the corresponding record drawings updated. Similarly, information on the state of a facility, the status of repair parts, or the contract or financial situation of a project is laborious to find and keep up to date.

If the owner has chosen to use a CMMS, this equipment and other building information must be converted to digital files. Typically, FM personnel do this manually as time allows. As a result, effective system use is delayed until the required data is available and has been checked for accuracy and completeness (IFMA, 2013). The data necessary to support a given phase of the life cycle only needs to be entered once, at the most detailed and accurate level available at the time. Following that, more information is added as desired and at the appropriate level of detail. By the time the building is finished and commissioned, the data needed for O&M should be accurate and usable. Current FM organisations have a plethora of data sources, many of which overlap. The goal of integrating BIM is not to add another information system but to help standardise data delivery, clarify data ownership, and facilitate access to validated data (IFMA, 2013).

2.3 Implementation of BIM in Facilities Management

FM personnel handles large amounts of asset information which needs to be acquired, updated and analysed. BIM can be used as a platform in the early stages of the building life cycle and allows for FM personnel to communicate their information needs in the O&M phase of the project (Wijekoon et al., 2018). According to Stride et al. (2019), one benefit of using BIM in FM is allowing FM managers to easily access digitally stored asset information, this is being used as a unified platform where the various data and information are required in operational FM activities are gathered. As a result, a BIM model can be used to rapidly provide information and data to perform any necessary analysis and evaluation in the O&M phase. There are traditionally various sources of this information, such as handwritten specifications, warranties, and operating and maintenance manuals, which are frequently comprehensive and fragmented (Aziz et al., 2016). Interoperability, real-time data access, space management, and energy consumption monitoring are some of the main value-adding attributes mentioned by Stride et al. (2019), with visualisation and locating building components appearing to be the most beneficial aspects of applying BIM in FM.

2.3.1 Interoperability

BIM provides interoperability and visualisation, which does increase the efficiency and functionality within FM and can be used to gather building information in an efficient way which may be accessed by anyone involved in the life cycle of the building. BIM thus improves communication service delivery, collaboration and workplace productivity among stakeholders (Aziz et al., 2016). Using as-built BIM models of the constructed buildings provides access to continuous updated information and specifications within the building's different objects and elements. BIM models can further be integrated with building system controls to be able to monitor real-time building performance and allow FM managers to fine-tune building equipment to optimise performance. Moreover, using BIM models instead of traditional paper blueprints, means that FM personnel can integrate real building components with 3D models and thus guide themselves through the model and instantly perform plans of action (Aziz et al., 2016). Furthermore, FM legacy systems could be utilised for one or two decades to come in existing buildings. This means that the value of BIM should be clearly shown and the transfer of data and information from BIM should be automated for FM managers to prove the business value of BIM in existing buildings (Kelly et al., 2013).

2.3.2 Information transfer

Utilising BIM in FM may reduce the need to transfer information to different FM systems, thus facilitating the use of the model to serve as a single point of reference for facility information, resolving interoperability issues between FM systems (Matarneh et al., 2019b). The information available in a BIM model ensures that the assets and equipment in the facilities are maintained in accordance with specifications and contracts. By extracting this data, FM managers can facilitate the use of scheduled maintenance and management activities and lowering maintenance costs (Stride et al., 2019). Additionally, this data could also enable FM managers to more easily locate building elements that require attention, thus resulting in less time and resources spent that would otherwise be used to perform these activities. Furthermore, BIM may be used to analyse how buildings behave and deteriorate over time, which can help with decision-making during maintenance, planning and operations (Aziz et al., 2016).

Implementing BIM in FM promotes a more efficient documentation system, and according to Matarneh et al. (2019b), may leverage FM practice by improving the handover process for new production buildings. Additionally, as mentioned by Aziz et al. (2016), BIM facilitates the handover process from the construction to the O&M phase due to providing essential information in a digital format instead of paper documents and blueprints. The handover process information usually includes product data sheets, operational and maintenance schedules, warranties, compliance data and equipment lists. These documents are traditionally provided manually in paper format, and are often inaccurate and incomplete (Stride et al., 2019). Utilising a digital solution such as BIM to replace these paper documents, means that BIM can be seen as a tangible asset that may increase the value of a facility (Aziz et al., 2016).

2.3.3 Energy Management

According to Matarneh et al. (2019b), BIM can be used to improve energy management. FM must monitor energy performance during the O&M phase in order to compare actual energy performance to set parameters. BIM can thus be used as a data conduit, collecting information from various stakeholders throughout the building's life cycle stages and then integrating and comparing this data with data from other energy management systems through an analysis. Furthermore, by being able to visualise sensor data in a digital environment of the BIM model, using BIM in energy management can facilitate decision making related to building energy consumption assessment and energy-saving management (Matarneh et al., 2019b).

2.4 Challenges

In a literature review, Dixit et al. (2019) emphasised the importance of an in-depth analysis of the issues and challenges of BIM-FM integration for the FM industry. The researchers reviewed 54 different studies and managed to classify the issues and challenges they discovered into four main categories. The four categories are BIM execution and information-management, technological, cost-based and legal and contractual issues.

2.4.1 BIM-execution and Information Management

In the study by Dixit et al. (2019), it is highlighted that underlying challenges with BIM execution and information management include issues regarding unclear BIM workflow, incorrect information capture, failure to update BIM information and a lack of client demand. Successful implementation of BIM depends heavily on information exchanges between stakeholders (Eadie et al., 2013). According to Becerik-Gerber (2011), several factors lead to unclear BIM workflows. These factors include unclear roles, unclear responsibilities, poor frameworks for BIM workflows, reluctance to share information, and a lack of guidelines for verifying or controlling BIM data which results in redundant efforts of building staff. Currently, FM personnel are not included in BIM workflow structures until the O&M phase, exposing them to large amounts of data all at once, which overwhelms them (Liu & Issa, 2013). A building's information volume increases progressively from the design phase to the O&M phase, making proper information capture of manufacturing data, specifications, operational instructions, procedures, and warranty vital (Becerik-Gerber, 2011). Therefore, for the BIM-model to remain relevant to FM personnel, it must be constantly updated to ensure the accuracy of the information contained in the model (Dixit et al., 2019; Liu & Issa, 2013; Becerik-Gerber, 2011). Despite this, there is a scarcity of information and case studies of built assets demonstrating the benefits of BIM for FM. As a result, clients are unaware of the implications of BIM for FM and fail to demand its use (Dixit et al., 2019).

2.4.1.1 Data Up to Date

According to Dixit et al. (2019), one challenge in BIM execution and information management for FM is the failure to update the BIM-model. For the FM personnel to effectively utilise the model, it needs to be frequently updated to ensure that the quality of the information is present (Liu & Issa, 2013). Moreover, Dixit et al. (2019) state the concern with this challenge is that process of updating the BIM-model is a manual process and thus time-consuming. Also, data duplication or data modification results in inaccuracies in updating BIM information and the inability or lack of mobile devices to update critical information in a BIM causes delays and errors in performing key FM tasks. As a result, FM personnel are unmotivated to provide the owner with continuous feedback in the form of an updated BIM. Updating FM information in BIM during the design, construction and O&M phases, would improve decision-making and problem-solving significantly, according to Dixit et al. (2019). Furthermore, when considering the comprehensive documentation of information required for effective O&M of most facilities, it is clear that finding efficient ways to collect, access, and update this information becomes essential (IFMA, 2013).

2.4.1.2 Knowledge gap

The FM industry and its cultural approach are one of the major challenges to overcome due to the slow implementation of new processes and technologies. According to Kassem et al. (2015), FM's conservative nature discourages the uptake of more modern technologies such as BIM, which results in a low adoption rate until some benefit of using BIM for FM is demonstrated. A lack of expertise in FM professionals regarding BIM is a significant challenge and is strengthened by a lack of guidance and standards which is contributing to the low adoption rate of BIM in FM (Pinti et al., 2022). This is further mentioned by Poulitaival et al. (2016) who state that a lack of knowledge, thus understanding both the BIM processes and the software, and the ability to remain current with the constantly evolving BIM-environment, are major hindrances to overcome when working towards BIM implementation. Moreover, the BIM adoption in FM is also inhibited by a lack of demand for implementing BIM in FM by clients, which is explained by a lack of client awareness. This is further aggravated by the lack of BIM skills and understanding by FM personnel, which in turn, creates a vicious circle. A detrimental challenge of BIM in FM to overcome is the continuous maintenance of the model to be able to keep its value, both for the building and its owners (Kassem et al., 2015).

2.4.2 Technological Issues

Technological issues of BIM in FM mainly occur, according to Dixit et al. (2019) due to interoperability issues between BIM and FM technologies, incompatible file exchange formats, large file sizes and long adaption times for using new software. Matarneh et al. (2019a) state that interoperability is the capability to exchange data between different software programs to promote automation and reduce manual data entry. Interoperability issues are primarily caused by incompatibility between FM technologies such as CAFM and BIM, which impedes the transfer of information and data to O&M. There is a need for open systems and standardised data libraries (non-proprietary formats) that can be handled by CAFM or asset management systems in FM. If these non-proprietary formats are not utilised, FM personnel is forced to apply proprietary information technologies and re-key information into CAFM systems. This means an additional cost of having the data keyed into FM systems (Kelly et al., 2013). Furthermore, incompatible file exchange formats are mainly the result of the use of several different application formats and middleware programs. Proprietary exchange file formats, which is a format that is developed by a commercial company meant to interact with other applications from the same company, are a part of this issue when using different types of software in the AEC industry. Moreover, incompatible file exchange formats are often resulting in information losses, a lack of communication and errors when information and data are transferred between applications (Dixit et al., 2019; Eastman et al., 2011).

An efficient workflow between BIM and FM will require data transfer among on-site and off-site personnel, however, due to large file sizes of the BIM model, creates issues for the on-site personnel and limits their ability to perform FM tasks (Dixit et al., 2019). To overcome this issue, the BIM file should be extracted into smaller file sizes to be able to store and efficiently utilise the BIM model in mobile devices. Real-time updates using mobile devices also apply to the construction phase, where it is commonly used, to additionally increase the quality of the FM data collection (Lin et al, 2013). Furthermore, the AEC/FM industry is generally known for long adoption times when new technologies are introduced. Kivits et al. (2013) state that the technology needs time to be explored, tested, and validated to understand its potential. Moreover, the complex interface of most BIM and FM software applications makes for AEC professionals to be hesitant of putting time and effort into understanding and using these applications for data management. This results in the use of both digital and paper-based media and the mix of digital and paper-based information, making it challenging to access, track, verify or trust the source of the data (Dixit et al., 2019).

2.4.2.1 Interoperability

Ozturk (2020) states that one of the main issues of BIM implementation in FM is to be able to transfer data between different systems and to effectively communicate data through integration and interoperability. Thus, interoperability could be a problem when using different systems that need to communicate. According to Chen et al. (2018), inadequate data integration is a common issue related to building information models due to differences in syntax schema or semantics. There are several levels of data interoperability, where semantic interoperability is the most applied linked to BIM data integration and other systems. Semantic heterogeneity of data is the result of different types of meanings or interpretations of data which may appear from various sources. This means that data integration and interoperability are inevitably connected when BIM and FM systems need to be integrated with each other. For instance, the data exchange process between BIM and FM systems has issues which particularly include integration between BIM and CAFM, which have been criticised for insufficient data interoperability such as the inability to transfer semantic FM information correctly (Matarneh et al., 2019a).

Furthermore, Matarneh et al. (2019a) state that recent attempts to improve interoperability between BIM and FM systems have been made by introducing universal data standards such as IFC schemas and specifications such as COBie. For example, when extracting information from BIM may result in an overload of information in the CAFM-system and one solution to this is to structure available data using COBie (Dixit et al., 2019). Although structuring data using COBie is necessary for FM, according to Kelly et al. (2013), COBie does not provide details on what, when and by whom the information is provided. Due to this limitation, data transfer becomes troublesome and limits interaction between stakeholders. To handle the issue of transferring data from standard data platforms such as COBie to FM tools, the development and use of plugins or application program interface (API) could be beneficial.

Moreover, Chen et al. (2018) have identified three challenges of data interoperability between IFC and COBie. Firstly, FM information requirements are different from the geometric and semantic information in the BIM models, thus the BIM model may only transfer parts of information to FM. Secondly, the data schema of FM systems and the BIM model is different, thus, BIM data is represented in the IFC schema and FM data is represented in COBie or a similar database schema. The third challenge involves data storage, i.e. BIM data stored in the BIM models is represented in for example IFC or XML format, whilst FM data is commonly stored and presented in a relational database such as Microsoft Excel or Access.

2.4.3 Cost based

According to Dixit et al. (2019), the cost-based challenges stem from the cost associated with training BIM personnel and information management together with the unperceived cost benefits of using BIM. Aside from the initial investment, the authors assert that building professionals must be trained to use BIM effectively, which requires considerable time and human resources. As a result, using BIM typically necessitates additional administrative and training costs (Eadie et al., 2013). On the other hand, Dixit et al. (2019) contend that the underlying issue for information management costs is a failure to invest in BIM, which leads to poor data management. As a result, the authors believe that FM personnel spend a significant amount of time verifying, locating, and separating appropriate data from the rest. Furthermore, the unperceived cost benefits of using BIM could originate from building owners failing to implement BIM in post-occupancy assets evaluation. Therefore, the as-built BIM model for an asset is not updated to reflect recent changes, resulting in increased costs and time-related issues to FM tasks (Dixit et al., 2019). Moreover, Beach et al. (2017) attribute the unperceived cost benefits of using BIM to the flexibility of digital data storage, eliminating the need for fixed-size storage spaces for paper-based media. By storing the data digitally in a cloud service, the information is easily accessible to the project's various stakeholders (Beach et al., 2017).

2.4.4 Legal and contractual

Dixit et al. (2019) mention legal and contractual issues connected to BIM where the most commonly identified issues are ownership and responsibility of the BIM data, contractual and compliance issues and cyber security and privacy. One barrier to address regarding legal issues is the inter-organisational process of operating and using one single complex file which makes it difficult to assign ownership and responsibility to the BIM (Kivits et al., 2013) Thus, to be able to determine the ownership of the BIM data and how it should be protected by laws and copyright is one legal risk to overcome. Furthermore, a challenge for BIM in FM is the lack of a contractual and legal framework for BIM implementation. Kelly et al. (2013) mention that contractual documents between different actors in the AEC industry are generally transferred through traditional paper and two-dimensional graphical forms. Thus, contractual documents are rarely generated from the BIM which makes it challenging to access, utilise and transfer the information to increase the efficiency of FM.

FM organisations are responsible to ensure safe and secure management and maintenance of facilities, thus, cybersecurity of digital data is an essential area to highlight regarding BIM implementation in FM. Cybersecurity threats include, for example, malicious software intended to destroy data or documentation, or granted access to unauthorised personnel outside the project team who may intentional or unintentional change data or information within a system (Ghadiminia et al., 2021) Additionally, a BIM model is usually containing sensitive information such as the location of entrances and exits and building layouts, but also confidential information in contractual documents such as digital signatures which means there is of great importance to ensure the safety of this information. Being able to secure the transfer of confidential information through cyber security policies, for example, could encourage the AEC industry to use a completely digital environment (Dixit et al., 2019).

3 Method

The chosen methodology for this master thesis is a qualitative research approach. Rather than generating statistics, modelling validation, and development, the qualitative research approach focuses on exploring attitudes, behaviour, and experiences (Dawson, 2007). As this thesis is trying to describe a phenomenon in context, the qualitative research approach has been chosen since the data gathered will be in a non-numeric form (Hammond & Wellington, 2021). By taking a qualitative approach in this research, patterns can be described, explored, and explained by illuminating the experiences and interpretations of construction actors with varying stakes and responsibilities. However, some critics of qualitative methodology results claim that they are too subjective and may be influenced by the evaluator (Toro, 2013). In this thesis, the issue of bias in qualitative data analysis has been mitigated by using both authors to code the data, having participants review our results and by verifying our results with additional data sources (triangulation).

The aim of this thesis is to address the value of implementing BIM in FM practice and how it corresponds with FM companies current work regarding digitalisation and their future vision. To be able to analyse and conclude the results, a combination of a constitutive literature review and interviews with people in consultant and FM firms is applied.

3.1 Literature review and theoretical framework

The purpose of the literature review is to establish what is already known about the subject of BIM in FM and the theoretical framework is framed to serve as a background and justification for the study (Bryman, 2018). The literature review conducted is in the form of a narrative literature review which provides a description of the research that has already been made in the studied area and is meant to introduce our own research (Bryman, 2018). Furthermore, the literature review is divided into three parts. The first part includes a definition of BIM and its application areas. The second part covers FM to provide the reader with a description of is current practices and technologies. The third part includes identified possibilities and challenges to overcome when implementing BIM in FM through practice and in theory.

3.2 Empirical data collection

The empirical data in this study was collected exclusively through qualitative research in the form of semi-structured interviews. The purpose of conducting interviews was to collect and gather data that could not be attained if quantitative methods had been used such as opinions, thoughts, and feelings from the interviewees around the subject (Hove et al., 2005). Semi-structured interview guides were chosen and structured according to topics which would be touched upon, and questions were asked in the order of origin and with the original wording. The choice of conducting semi-structured interview was to make the interviewees formulate the answers in their own way, and to give the possibility to ask questions not included in the interview guide, if referring to something said by the interviewees which may have needed a deeper explanation (Bryman, 2018).

A total of 9 semi-structured interviews with consultants and FM representatives from different organisations in the construction industry was conducted. The roles of the respondents are shown in Table 1 & 2, for the consultants and FM companies respectively. All of the conducted interviews involved one respondent except FM company F which included 4 interviewees, this was a spontaneous decision from the initial respondent who offered to invite 3 colleagues which all had different knowledge areas within FM.

The aim was to get a broader perspective on their current and future digitalisation state and their view on BIM implementation in FM. Moreover, the interviewees that were chosen had different levels of BIM experience, including both the design and production stages and operations and maintenance, thus each company with varying contributions to this study.

The interviews were conducted via either Zoom or Microsoft Teams and were divided into shorter and longer durations why the interviews lasted between 15 and 60 minutes. Initial questions involved the interviewees background to get a more personal experience for both parts. Afterwards, the questions were focused on the subject of this study and follow up question were asked when needed. The shorter interviews were specifically conducted to get an overview into both consultants and FM companies view on BIM implementation in FM practices. The longer interviews were conducted to focus on FM companies has experience in practicing BIM in FM, and also companies that has a vision of implementing BIM in the future. Additionally, the aim of the longer interviews was to give a deeper understanding into more specific areas relating to BIM in FM. All of the interviews were recorded and then transcribed in order to focus on the interviewee and to not miss out of any important information.

Table 1. Consultant respondents.

Respondent	Role	Experience (Years)
Consultant A	Project Manager	20
Consultant B	Civil Engineer	9-10
Consultant C	Business Developer	5

Table 2. FM respondents.

Respondent	Role	Experience (Years)	Groups
FM representative A	Head of Management	27	Not currently interested in BIM
FM representative B	Head of Technology	9	Interested in BIM
FM representative C	Head of IT	7-8	
FM representative D	Project Manager	20	Implementing BIM
FM representative E	Head of Business development	25	
FM representative F*	Digital Information Manager, Business Developer for FM, Digital Information Manager, Project Manager	5, 30, 11, 25	

*Four respondents were present during the interview

3.2.1 Ethics

According to Ryen (2016), some qualitative research tends to invoke an image of risks and threats for the research subject, necessitating external control and reaction. Thus, Kang and Hwang (2021) argue that while conducting qualitative research, researchers must uphold informed consent, confidentiality, and privacy, adhere to the principle of beneficence, and practice honesty and integrity. As a result, caution must be taken when the actions and expressions of those involved can result in unwanted exposure, loss of standing, employment, and a sense of self-esteem. It is therefore imperative that researchers exercise extreme care. With regard to the information, consent, confidentiality, and use of data, the study was conducted according to the general requirements for research ethics set out by the Swedish Research Council (2017). The interviewees were kept anonymous in order to protect their privacy and ensure the reliability of their answers. Because the interviews were all recorded, each participant was asked to consent before the interview began.

4 Results

This chapter presents the results from the conducted interviews and thus providing the empirical data for this study. The interviews were constructed to map and highlight both the consultants and FM companies main take on the possibilities and hindrances of applying BIM in FM. The first part includes the results from the interviews starting with a general perception on the consultants view on applying BIM in FM, and their experiences working with FM companies. The second part includes the view of FM companies not currently applying BIM in their operations and gives their take on digitalisation in FM practices and BIM implementation. The third part summarises the view of FM companies that are currently implementing BIM in their operations and provides their experience regarding main possibilities and challenges of BIM.

4.1 Consultants View on BIM implementation in FM

The following interviews presents the findings from two consultant companies working with BIM mainly in the design and production stages, and one consultant company with general BIM expertise in all project stages.

4.1.1 Consultants and Facilities Management

According to the consultant interviews, FM has a different focus and time horizon than the design and production teams. More often than not, the BIM model that has been created in the design phase and used in the production of the construction phase gets cut off, and the utilisation of the model ceases to exist during the O&M phase. The interviews also revealed that the consultants had little to no knowledge of how FM works apart from that FM is a hands-on type of work where drawings and documentation are apathetic. As consultant A said;

"... I think that to many of us working in the construction industry believe that the FM industry seems like a mystery" – Consultant representative A

Consultant C believes that FM is dependent on two levels of information, with as-build documentation being the first level and the second level consisting of information about installations and product manuals. The first level of information is mostly connected to area information, in consultant C's words:

"If you were to make a fairly simple breakdown [of the first information level], I would say that FM are most interested in the Area information. Area information is a crucial controlling factor in the building's revenue and is also used to break down other types of calculations or expenses on the." – Consultant representative C

As consultant C further explains, FM needs to know how much space they have available to rent out to their customers. This, to be able to rent the right kind of space and to clearly understand the type and amount of space they have. The second level of information that FM is interested in is about the building's installations and products. As stated by consultant C:

"There are numerous types of inspections and other requirements that you must comply to as a property owner in order to monitor

your building. ... This means that there are certain objects or components that are so important that you must know where they are and what type of component they are." – Consultant representative C

4.1.2 BIM definition and BIM in Facilities Management

The consultant interviewed in this study had similar statements regarding BIM. As explained by the interviewees, BIM is a methodology for describing assets in the form of a 3D model, which is rich in information and is typically used during the design and construction phases. There are, however, some differences in the definition of the acronym BIM. BIM is defined as Building Information Modelling by consultants A & B and Building Information Management by consultant C. Consultant C believes that with the distinction of BIM as Building Information Management, BIM encompasses all the processes and information surrounding the entire asset. As stated by consultant C:

"BIM is more than just a single system. It [BIM] is about more than just a single model; it is about the processes, the systems, and the people who work with it." – Consultant representative C

Nevertheless, the consultants have high hopes for the FM industry and stress that there is a lot of untapped potential and benefits of BIM that they have yet to realise. Moreover, the consultants in this study emphasised that it is already possible to allow for streaming data via a 3D model such as Digital Twins, but the technology is rarely utilised in practice, as consultant B stated,

"The technology exists today, but no one is using it." – Consultant representative B

Although the technology is available as of today, one step in the right direction, as the consultants all agree on, is that FM could start by receiving and archiving the BIM models from the handover process. However, according to these consultants' experience, FM only wants to receive maintenance manuals and drawings in PDF-format. The consultants emphasised that they, in most cases, need to push the thought of handing over the BIM model to FM even if they are reluctant to accept it. As consultant A said:

"For a long time, we've been wondering how FM would like to receive the model. Then we discovered that they are unaware [of how to set requirements on the information/model], and that it is something they have not considered." – Consultant representative A

4.1.3 Challenges: Knowledge gap & BIM software's

The three consultant representatives interviewed in this study are in consensus when it comes to the challenges that inhibit BIM implementation in FM. One of the most difficult challenges that FM faces when attempting to implement BIM in their organisation is deciding which software's to use. Therefore, the consultants suspect that the reason for the distancing that FM has toward BIM could be that there is too much BIM software out in the market and that FM managers lack the knowledge to operate those software's. As a result, the consultants believe that it is critical to inquire about the tools and systems that FM uses and is reliant on in order to understand their working conditions. According to consultant B:

> *"... you have to look at the FM systems in order to see what systems they have today and how it works. I believe it is very much linked to Excel."* – Consultant representative B

As a result, consultant B believes that the information handled by FM managers is connected to spatial area information, localisation and physical asset information, without the link to a model because the use of Excel is general practice. However, there still is consensus amongst these consultants that another inhibitor for BIM implementation in FM is the lack of knowledge on how FM want to acquire the model and the information within the model. Consultant C has found that FM organisations often do not know exactly what information they want. Therefore, the interviewee speculated that their uncertainty about how to set their demands is the result of their lack of knowledge about the programs and systems required to utilise the information from the BIM model. As stated by consultant C:

> *"The programs [BIM programs] are not designed to maintain a model indefinitely. As a result, there is a lack, or has been historically, of good software that FM can use to see their information that is built based on their user needs."* - Consultant representative C

This is a challenge according to consultant B, who claims that many of the FM companies often do not know what they want other than a product, and even fewer understand the benefits that the BIM model can provide. Consultant B frequently advises the FM organisations to at least receive and save the BIM model because if they need to make changes to the building in the future, they will already have a BIM model ready and will not have to perform a 3D scan in each building to create a new model.

4.2 Facilities Management companies view

This chapter will present the results of the interviews with 6 large FM companies in Sweden, both private and public owned. The findings is structured according to the degree of BIM knowledge and interest in the concept. The first section will focus on the findings a company who did not show interest in BIM as of today, followed by results of companies who are interested in BIM but have not yet implemented the concept. Finally, results of companies who are utilising BIM in current projects.

The results from each group were structured according to the topics most often discussed during the interviews. At first, the results will begin with the respondent's definition of BIM. Afterwards, the interviewee's answers regarding what barriers they have encountered during their journey in implementing BIM will be presented, followed by the prospects they have about BIM. Table 3 shows the result from the interviews with the FM representatives where identified topics of challenges of BIM in FM from the theoretical framework is combined with the main empirical findings and the table pinpoint the most commonly mentioned issues.

In summary, as shown in Table 3, the main challenges identified from the interviews was information requirement and data-up-to date, with knowledge gap and information quality as the second most common barriers.

Table 3. Summary of the key findings from the interviews.

From theoretical framework	BIM execution and information-management challenges					Technological challenges		Cost challenges	Legal challenges	
From interviews	Information Requirement	Knowledge gap	Delegate responsibility	Data-up-to date	Information Quality	Proprietary formats	Legacy of old systems	Unperceived cost benefits	Owning the data	BIM is a legal document
FM Representative A								x		
FM Representative B	x	x	x	x			x	x	x	
FM Representative C	x			x		x	x			
FM Representative D	x			x	x					
FM Representative E	x	x		x	x					
FM Representative F	x	x		x	x	x				x

4.2.1 Facilities Management company not currently interested in BIM

4.2.1.1 Current workflow state and BIM

According to FM representative A, they do see some benefits of implementing BIM in O&M however, they have not seen the need of a BIM. It seems that they aspire to be fully digitalised as a company, although they do adopt and finds solutions where they see a fit according to their business plan. Regarding BIM implementation, FM representative A states:

> *"It is super cool to have everything gathered in one place, but we still have it in our own way and it's a bit typical in the way that we like to work. We do often find our own ways to do things"* – FM representative A

Due to the contentment of their current state in O&M where they have a stable workflow, FM representative A states that they do not have a vision of BIM implementation in their operations in the nearest future. One example of their current workflow in O&M is that they rely on their own facility systems where they collect all information needed. Additionally, the interviewee highlights that they have most of their system development in-house which means that they can adapt the business to coming needs.

> *"We are pretty fast-footed as a company, so if we see a need, we do something about it, it is not more difficult than that"* – FM representative A

It is further mentioned by the interviewee, that there must be a financial gain in the end when implementing a newer technology such as BIM, either in terms of cost reductions or less time spent on searching for information. As of now, they do seem to have good management in O&M with their own different FM systems, thus lacking the need of a main system, which according to the interviewee, BIM could be utilised as.

4.2.2 Facilities Management companies interested in BIM

4.2.2.1 BIM definitions

The FM companies that are not currently implementing BIM in the O&M phase lean towards the definition of BIM, as an overall model for the entire building and a digital representation of the building that contains information of the ingoing part. As FM representative B stated;

> *"It [BIM] is a model or Digital Twin of a house, which contains all the information regarding how the house is built and what different parts that are included"* – FM representative B

4.2.2.2 Legacy of traditional Facilities Management systems

FM representatives B and C agree that they mostly use a legacy of traditional FM systems but are aiming towards making better use of data warehouses and new easy-to-handle tools. Today, data is handled in several specific systems used in the FM industry and thus where most of the master data is collected. FM representative B highlights that one issue in FM is that there are too many different information systems which is the result of a lack of coordination in the procurement of systems. The interviewee further mentioned that a few decades ago, FM companies did not think ahead regarding the utilisation of systems. For example, FM companies would just acquire a new key management system if needed and not care for incompatibility, as mentioned by the interviewee.

> *"Today it would be great if everyone had bought the same key management system because then you could acquire the information in that system and be able to use it for other things in the future"* – FM representative B

In the future, representative C mentioned that FM would benefit from utilising open-source systems where it is possible to transfer data in a free and open way. In this way, it will facilitate more opportunities to analyse and use information in the future that may lead to the creation of new services linked to information sharing.

4.2.2.3 Issues in keeping data-up-to-date and Delegate responsibility

According to FM representatives B & C, one of the more problematic changes that FM organisation must undergo when adopting BIM is the need to redefine and change work processes within the company. FM representative C believes that the integration of a BIM model will necessitate a shift in traditional FM roles to accommodate the new working method of collecting and storing information related to property management. In the same vein, FM representative B believes that, while this type of change is necessary, it will also be difficult due to the traditional nature of the FM industry.

FM representative B further elaborates that for BIM models to stay beneficial in FM throughout the building life cycle, they must be frequently updated. However, the interviewee also disclosed that FM has an ongoing issue in the industry connected to updating paper drawings. As described by FM representative B:

> *"Just by looking at the ordinary drawings, we can't even manage [update] them properly. Over the years, the drawings become irrelevant because you rebuild but do not update the drawing. The most difficult aspect of this type of documentation is keeping it up to date."* – FM representative B

The interviewee further stated that a change in working duties necessitates a tremendous amount of control over all the information associated with the BIM model, thus, as soon as changes are made in a building, one must ensure that all necessary changes are incorporated into the model. In the same notion, FM representative C emphasises the importance of delegating this responsibility to ensure that this task is completed.

4.2.2.4 Information requirement and Knowledge gap

The FM representatives B & C agree that BIM is commonly used in the design and construction phase of their new building projects, however it is mentioned that these models are only archived at the FM company after the handover process and not actively used in FM. Thus, there seems to be unclear how they should exactly utilise BIM-models in O&M much depending on the lack of need. FM representative C highlights that after the construction phase is finished, the structure of the handover process of the BIM-model to O&M is missing.

> *"The problem seems to be that the systems used in O&M are not mature enough to be able to transfer this type of information"* – FM representative C

Furthermore, due to the data-driven culture in O&M, it difficult to receive and utilise all the information connected to a building gathered in the BIM-model. Thus, only a minor part is transferred, and a lot is transferred manually to different types of systems, which means, that much information is lost in between these transfers, according to the representative C.

4.2.2.5 Cost & Legal Challenges

The legal aspect of owning the information and data in the BIM model was raised by FM representative B as a challenge. The interviewee went on to say that it is critical to select the right system supplier to avoid having the data for that specific system locked up. Furthermore, FM representative B further elaborated that the primary purpose of the data and information collected in various FM systems is to be used by distributing it to other systems. However, a challenge that was only briefly mentioned in this group was the cost. In this matter, FM representatives B and C agreed that the cost challenge is related to the organisation's vision of BIM. They went on to say that for BIM to be of use in an FM organisation, they must first see the benefits of incorporating BIM into their operations. FM representative B also stated that it is critical not to set overly difficult targets for BIM utilisation. Another cost issue raised by FM representative B was the need to update the BIM model after renovations or changes to the building and the cost connected to this work. Additionally, depending on the renovation work, updating a model to match reality could be costly.

4.2.2.6 Development of BIM in Facilities Management

FM representative C states that in the future that they will, like many others FM companies, look into how to start using new cloud services in a more efficient way linked to O&M. Another focus area is energy and heat demand in properties and how to use AI for optimisation. For long term purposes, they are investing in the development of a more centralised management of energy data where they can optimise and predict maintenance in a more effective way and thereby have a more efficient operation of their properties. Further, the interviewee believes that the FM industry will move towards a more data driven culture and states:

> *"In the future, I believe that FM companies will become much more like technology companies than they are today, thus become more data-driven as we see some other tech companies have developed. I think it will move over to the FM industry, not completely but parts of the data driven culture will change the way we work going forward, and also roles and responsibilities and things linked to how we how we manage things today"* – FM representative C

The interviewee also believes that FM companies needs to be organised to be able to handle the digitalisation process efficiently, and highlights that this is especially important to be able to track how information and data are used. Thus, organisations need to adapt to how to structure and collect information in the future linked to O&M.

> *"Traditionally you have a FM host, a FM manager and a head of FM, this is how the structure looks today and I think we need to divide it, partly because I think that the manager role today should solve many different types of problems"* – FM representative C

FM representative B stresses that, in the near future, they aim to have portals that collect information efficiently in different contexts, both internally and externally. The goal is to automate data processes to move away from being person-dependent and making data available to those who need it, this to save time and resources. However, FM representative C further mentions challenges connected to digitalisation, which is an increased demand on cybersecurity, such as securing networks in different ways.

> *All these opportunities that new technologies provide are also given the opportunity for vulnerability gaps, here we need to sharpen up very much linked to cybersecurity.* – FM representative C

Ultimately, there are clear challenges to overcome regarding digitalisation and implementation of new technologies, as stated by FM representative B:

> *"There are many challenges in what makes us need to do this digitisation journey. If not before, then at least in parallel with the use of BIM models"* – FM representative B

Furthermore, FM representative C mentions that applying BIM means that FM has access to complete information about what the facilities look like and what is included, resulting in a more efficient follow-up process of things used in the building. In the long run, the interviewee further believes those who work within the facility, i.e. FM hosts with simpler interfaces and management such as mobile solutions, could also update and quality assure the information effectively. Ultimately, if data is connected to a Digital Twin of the building, FM representative C states additional benefits for FM.

> *"A Digital Twin will ensure the quality of information handling in a more efficient way connected to areas which is the most important data we have"* – FM representative C

Moreover, the interviewee mentions that BIM makes it possible to objectifying at a level that fits with the organisational requirements and believes that BIM is one prerequisite for being able to build Digital Twins, in combination with positioning data, in the future.

4.2.2.7 Sustainability

FM representative C mentions that one of the major challenges the industry is facing is how to reduce energy costs which is connected to what is mentioned by FM Representative B. The interviewee states that the consultants they are working with, use BIM with ready-made blocks from different suppliers and which makes that information very important because they only build according to Miljöbyggnad in new building projects. This means that they need to log all included products and the important parts and one example is information regarding U-value in walls, windows, ceilings and different materials. According to the FM C, one benefit of the rise of ICT facilitates sustainability reporting, i.e. being able to create real-time ESG (Environmental, Social and Governance) reporting via connected sensors which thus generate data automatically. This reporting is important due to that they are linked to the loans they have with different banks. Thus, the bank makes demands in order to allow FM organisations to be able to borrow cheaply, which means that they need to fulfil the requirements that have been set for "green loans", for example.

4.2.3 Facilities Management companies implementing BIM

4.2.3.1 BIM definitions

The interviewees implementing BIM seem to agree that BIM is not just a model but also a way of working that need to be implemented. One interviewee of FM representative F mention that BIM is associated with is parametric modelling and that BIM is a design tool which is meant to being able to work with projects in a streamlined format and efficient way. FM representative D have a similar opinion and states that BIM is a production tool for construction at its core. However, the industry has begun to come to the realisation that there is a lot of information in the BIM-model that is not utilised and could provide future benefits for FM.

> *"The BIM model is built for production, it is not built for management, if we are to get the benefit we want, then we have to tweak the model to what we want out of it"* – FM representative D

It is highlighted by FM representative E that BIM stands for two different parts. In one end, BIM is associated with Building Information Modelling and in the other Building Information Management. Outside of the modelling point of view, the management approach is focusing on how to handle information and what can be achieved with the information in value-creating processes. Whereas modelling is more connected to extraction of information, additions, and descriptions.

4.2.3.2 Change in working practices and Keeping data updated

The hindrances of BIM application in FM are closely related to a new digital way of working, according to FM representative E, and the lack of knowledge in FM is an important part to bridge. In FM, there is a habit for a certain way of working and by moving towards a digital way of working is equal to a different type of work which may be part of the obstacles to overcome. One step in the right direction is that more people should use these tools and methods to be familiar with them. The organisational work is another challenge according to an interviewee of FM representative F:

"FM need new roles, both roles and working methods need to be changed to really benefit from BIM" – One of the FM representatives F

Connected to a new digital way of working, the FM interviewees E & F all agree that it is important that all the information in the digital databases and all of its connections are correct. There are connections and relations to all the objects that is created which works efficiently if all of the information is correct, however when information is incorrect, there are several things that can fail. Thus, a challenge seems to be able to get the right information and keep the information up to date over time.

"After all, another type of accuracy is also required in the information handling when using digital working methods" – FM representative E

One advantage of utilising a BIM-model, allows for an incredible amount of information available according to the interviewee. Contrary, sometimes too much available information is problematic which makes it difficult to set a reasonable level, both on how detailed the model should be, but also how much information should be entered in the model. Often the problem seems to be that often times too much information is gathered in the BIM models for FM to manage. Thus, it is important that the information available in models to be relevant, valuable, and kept up to date. A major part according to the interviewee, is when they do share information, that everyone take responsibility for making sure that the information transferred is correct and reassures its quality.

"We must also be able to trust the information we have in the model and there I believe we have a challenge" – One of the FM representatives F

FM representative D further highlight the importance of keeping the model up to date and which is one of the challenges in BIM implementation. The interviewee mentions a project where a BIM model is used in design and construction to the O&M phase. They do know that the model is incorrect as of now due to changes that has been made in reality, although, they have not been able to keep up with these changes to correct the model. The interviewee states that it is important that every change is updated in the model to develop a continuous process to not make this an obstacle.

Additionally, obstacles in BIM implementation are somewhat dependent on its extent, according to FM representative E. The interviewee states that a lot of work is required to get a complete digital restoration of the property portfolio of a large FM company, however it may not be a major problem for a smaller company. During the transition to a digital property portfolio, FM representative E stated:

> *"You get a time period where you might live in two worlds, the old world and the new world and you should keep everything up to date"* – FM representative E

4.2.3.3 Information requirements and Knowledge gap

The general lack of knowledge around BIM and its use in FM is a problem which hinders the use of BIM outside of the design and construction phase, according to the interviews. Thus, interviewees from FM representative D and F put emphasis on requirements of BIM in construction projects. As mentioned by interviewee D, one way is to facilitate use of a BIM Execution Plan (BEP), which provides clear requirements of what the BIM model should include and what information is needed by FM. Moreover, an interviewee from FM representative F states that they currently do not put demands or requirements for working with BIM in FM.

> *"Usually, the project hire consultants because they are efficient in managing BIM by performing collision check and do calculations etc. Thus, the consultants have been given the opportunity to work with these areas without us actually getting involved"* – One of the FM representatives F

However, according to the interviewee, they do want to be more involved in what type of information it should include and thus decide what the original model should look like. Although, due to the format requirements of BIM specific software, which they do not use in FM, means that they will not handle the model itself, according to the interviewee.

> *"Revit, or equivalent, is not a program that should be used for FM personnel to handle information. Me personally do not know enough to guide myself through and get lost in that system"* – One of the FM representatives F

Instead, they would require an open-source variant to be able to utilise the information and present the information internally in a way which is more understandable for FM personnel.

4.2.3.4 Issue of Proprietary formats

The interviewees share a common opinion that to be able to perform efficient FM practice, open-source programs and easy-to-use tools is needed. Thus as one problem of using BIM that is mentioned by an interviewee of FM representative F, is that you become dependent on the original file format, or the proprietary format.

> *"Proprietary formats I would say is a big problem for the industry, especially for the public actors"* – One of the FM representatives F

This problem, as the interviewee mentions, is mainly connected to procurement. On one side, the procured consultants should be able to handle different types of software and if projects have their own procurement and has the original file is in a specific format, then the procurement of project actors must be based on that specific format. One example that was brought up by an interviewee was that the design and construction phases of the project lasts only a few years of the total building life cycle, however, the building is meant to last for 50 to 100 years, thus more focus should be put on O&M. Additionally, if information and data connected to the building should be reused for future renovation projects, it is important not to be locked to one specific format by a specific software vendor.

> *"We need to start thinking more openly. We need to start thinking more open source and therefore I want to put more emphasis on a BIM-model customised to fit FM needs because O&M is actually the majority of the building's life cycle"* – One of the FM representatives F

Although open source formats, such as IFC, is utilised for data exchange, the limitation of IFC is that it is not editable. The interviewee highlighted that the main thought of using a proprietary independent (open-source) format as IFC is to facilitate the exchange of data, however like a PDF-file, it's not intended to be edited, which is an issue for FM.

4.2.3.5 Legal aspects

One of FM representative F mentions that there are a few different aspects to the legal issues regarding BIM implementation. One issue is that the AEC/FM industry is still dependent on paper drawings.

> *"I think you can gain great benefits from BIM if we start moving away from drawings because it takes an enormous amount of time and resources for designers to create very detailed paper drawings"* – One of the FM representatives F

Further, there is lot of information that should be added alongside the correct stamps on the drawings, according to the interviewee. Thus, a building project could include hundreds to thousands of drawings which is depending on the size of the project. Additionally, one major issue is if something is changed or is incorrect, then all drawings must be revised manually. The interviewee mentions that it is the traditional drawings that today is a legal document but highlights the potential of the BIM model to be used as a legal document, such as a As-built documents.

4.2.3.6 **Development of BIM in Facilities Management**

One of the FM representatives F states that the concept of BIM in O&M is not correct or relevant, instead, it should depend on the specific organisation and what system solutions they use. For example, in a known ISO standard for BIM the term BIM is not specifically used in O&M, instead the term Asset Information Model (AIM) is used. According to the interviewee, it is the data that the BIM file contains that is interesting, not the BIM concept itself, thus the Asset information model is a BIM customised for O&M. AIM contains necessary data and information required for FM operations and allow the utilisation of open-source formats. As stated by one of the FM representatives F:

> *"We need to think more open source thus FM should put emphasis on the Asset information model and view BIM more as a design tool"* – One of the FM representatives F

Furthermore, the interviewee states that digitalised processes go in different stages. One example mentioned, is making a digital inventory of buildings through 3D scanning, and thus get automated quality assurance and an inventory at the same time. Thus, ensures the quality of the BIM model, which in turn will become an AIM. This is where digitalisation begins, according to the interviewee.

The interviewee further mentions that by utilising an IFC from the BIM directly into an asset database, which acts as an integration engine between the property system and the graphical business support, means that FM personnel can both work with the IFC file continuously and visually view the model. The data from the BIM will thus be made available through the entire O&M organisation, and since it is connected to the FM systems, both areas and installation objects will be available in the database. The interviewee thus mentions a new way of a digitalised work process when utilising the AIM:

> *"If you think about existing information processes and workflows, it (AIM) will definitely replace workflows. The AIM will make existing types of information more accurate, more reliable and contribute to better information management in the future"* – One of the FM representatives F

Additionally, the AIM will also form the basis for developing the digital twin, which is an integration of both point clouds, panoramic images, BIM data, the property database and streaming data, according to the interviewee.

Moreover, the database, to which the Asset information model is linked, will have a validation function. This means that when a delivery from a project is received, then each object that are interesting for FM, such as installation-required installation components, will receive a specific ID that tells that this object is unique. In the event of a rebuild, then these ID markings will remain, which means that if it is decided to reuse for example, installation components, then it is possible to track and ensure that change in the project.

"This will be a completely new way of being able to track objects and assets that can definitely be valuable from a recycling perspective" – One of the FM representatives F

Furthermore, FM representative D also mentions prospects of a customised BIM model which is a representation of a Digital Twin called Facility Information Model (FIM). This FIM is a sort of simplified BIM model due to only incorporating relevant information utilised in FM. However, it is also possible to connect several other sources of information in the FIM system, which also makes it more complex, according to the interviewee.

"The FIM model is simpler, but it's more complex on the other side" – FM representative D

The interviewee further states that the FIM is meant to provide the possibility to click and find objects and import Property sets from the BIM model. The goal, according to the interviewee, is to use the FIM as a portal to integrate FM systems. This will provide easier management of problems or issues occurring in the facility, such as notifying if there is an alarm in the control system in case an object has been damaged, or if something does not work properly. Based on what kind of problem or issue that is detected, it is possible to get the necessary information by clicking on the alarm and be automatically transferred to the main system, thus the FIM system itself will only act as a digital portal.

"If you click on an alarm you will be transferred to the SCADA-system, if you click on a document link you will get to SharePoint or Greenview" – FM representative D

The main point of using the FIM as a portal is that it eliminates the need to keep track of documents, quickly get hold of statistics and easy access the right information when needed, according to the interviewee. The following example around the possibilities of utilising the FIM is mentioned:

"Now this machine is broken, so the operations technician is like: OK, I need to get hold of the operation and maintenance instructions, I need to know who to call and so on. Based on that, they should just be able to click in the FIM and quickly get the information they need" – FM representative D

FM representative E mentions that BIM is applied in all of their new production projects and that they work according to a concept called Total BIM. Here, a number of other parameters is added to achieve a more production-adapted design and thus a more efficient and productive construction phase. The BIM-model itself is one part of Total BIM where data is added, which facilitates a more flexible working process in real time in design, and provide information to perform analyses and planning.

Moreover, the interviewee stated that in O&M, they do work with a more tailored BIM for FM practice that they call a simplified BIM, however, these models are not involved in the design and construction phase. The simplified BIM models include the same basic structures that BIM provides such as object-oriented models where it is possible to connect FM-oriented information and thus, avoid an overflow of unnecessary information that is not utilised in FM.

One interviewee of FM representative F believe there is an advantage of creating a smart BIM-model such as a Digital Twin that is based on BIM data, where it is possible to perform different simulations and optimisations. The interviewee mentions one example of using a Digital Twin to simulate the ventilation and be able to see how it changes when new elements is added to the model.

Additionally, one benefit of the Digital Twin is that it provides the possibility for customers to get a virtual view on the buildings or premises before they buy or rent, which means that the customers do not need to view the premise in reality as a first impression.

> *"If we look at our student housing, for example, the possibility to get a home viewing without being on site as a student it is a great thing. Too many times you do not live in the city you are moving to and in this case, you can see your apartment in advance"* – One of the FM representatives F

4.2.3.7 Sustainability

One of the FM representatives F mentions that the focus of their goals and strategy around sustainability is to strive to rebuild more than to build new. The interviewee further highlights the importance of demolishing or rebuilding in a way to be able to reuse parts for future projects. Thus, it will be important is to have the BIM model updated, mainly to have a correct model to work with when the rebuild is finished. Combined with 3D scanning of the building during the construction period, will visually provide how it is built inside the walls, where things are located and what is included. Furthermore, another interviewee from FM company F agrees that BIM provides easily access to information and reuse of data connected to the building, which means that time is saved as all necessary data is available in the BIM model and thus less time spent on locating and reuse data in comparison when relying on paper drawings. The model thus works automatically as a basis for future renovations or rebuilds because there will always be changes in the buildings, according to the interviewee, and highlights the importance of having the model continuously updated from the start. One example of the advantage of reusing data from the BIM model for future changes as stated by the interviewee:

> *"I can imagine that in 20 years we might discover that some carpet glue we used between 2020 and 2023 is not good. It needs to be replaced and thus we need to be sure of where and in which facilities we have used this glue. How many square meters do we have where it is included, what will this cost us? etc. Such things could be relevant, or that you should be able to count the number of door handles because we must replace them all, thus, how many are there and what does it cost?* " – One of the FM representatives F.

Additionally, one representative of FM company F mentions that BIM facilitates traceability for products, materials or objects used in the facilities. The interviewee goes on to mention the food industry and the pharmaceutical industry and traceability, where there is according to the interviewee, one hundred percent traceability from producer to consumer. The AEC/FM industry is although today lacking in this area in comparison, however, in the future it could most likely be possible and would be optimal to trace and detect serial errors in production lines for objects or products used in facilities. Such as, if serial errors are detected and then it should be possible, in theory, to go into the BIM database and quickly identify which products or objects it involves.

"We have 42 of these pumps that come from this production batch and there is a great risk that they are wrong. Then you can go in to the BIM and pinpoint them or work preventively." - One of the FM representatives F.

5 Discussion and analysis

This chapter compares the theoretical framework of the thesis with the main findings from the conducted interviews where the results is analysed and discussed. The chapter have a similar structure as the previous chapters with the following headlines: Empirical findings, BIM, Prospects (Future of digitalisation of BIM in FM, Development of BIM in FM), Challenges (BIM execution and information management, Technological, Cost & Legal) and Sustainability.

5.1 Empirical findings

When the data collection of the findings from the interviews was finished, the FM representatives was divided in three different groups in accordance with their experience and general attitude towards the concept of BIM in FM. The groups were as in previous chapters mentioned, categorised 1) not currently interested, 2) interested and 3) Implementing. FM representative A was included in the currently interested category due to the respondent being sceptical towards the implementation of BIM in their O&M, mainly due to their organisation being satisfied with their current workflow and to the lack of proven value of utilising BIM in FM. The respondent thus only mentioned the unperceived cost benefits as a challenge. The interviews with FM representatives B and C resulted in a group of interested due to their clear digitalisation agenda and future vison of BIM integration. Also, their knowledge around the concept and an overall positive attitude towards BIM put them in the interested category.

The FM representatives D, E and F all had experience with BIM in their FM practices and was well educated in the BIM concept and thus were grouped in the implementing category. The implementing group did not only share their thoughts around the challenges and hindrances, but also their own development of the BIM concept to fit their specific organisation.

5.2 BIM

According to the findings of this study, each respondent has their own understanding of what BIM entails. Drawing on Eastman et al. (2011), the consultants and implementing group of this study appear to understand the concept of the parametric object and how these objects can automatically modify associated geometries at various levels of aggregation. Even though all of the FM companies interviewed for this study could define BIM, it became clear that many of them only saw BIM as a technology and ignored the processes perspective, as noted by Azhar et al. (2012). On the other hand, it became apparent that some of the FM companies in the implementing group referred to BIM as what McArthur (2015) defined as Building Information Management.

All of the FM companies interviewed in this study emphasised that BIM will be a platform where they will collect data and connect or integrate other FM systems and sources of information with the BIM model as a visualisation tool. Despite the similarities in BIM prospects, there are some differences in how the interested and implementing groups perceive BIM. Companies in the implementing group understand that BIM is more than just a production tool and that if FM wants to reap the benefits they seek, they must tweak the model and find a way to work with the processes perspective. This disparity could be explained by the fact that the FM companies in the interested group are still in the early stages of their journey, trying to discover and realise the benefits of implementing BIM in their organisation.

5.3 Prospects

5.3.1 Future of digitalisation in Facilities Management

The findings from the interviews showed that the FM representatives see value of implementing BIM in their O&M. As the FM industry in general seems to utilise traditional systems and data handling is performed in several different systems in accordance with the findings, the need for a joint information system or platform seems apparent and would most likely lead to a more effective FM practice. This resonates with Stride et al (2019), where it is highlighted to that BIM could be used as a unified digital platform which would provide immediate and efficient information and data access for O&M. Furthermore, the BIM implementation seems more credible for FM representatives B and C in accordance with their vision of digitalisation. However, it appears from the findings of FM representative A, that utilisation of BIM in their operations in the near future is lacking due to their current workflow. Today, they rely on agile adaptation to oncoming needs and in-house system development and are thus satisfied with their current state and therefore BIM implementation is not on their O&M agenda. Although, it is not unlikely that they will implement BIM in O&M if the investment is proven valuable and more FM organisations utilise BIM with good results.

Furthermore, in accordance with the findings, FM representative B and C mentioned that they are working with utilising technological solutions for more efficient and sustainable O&M. As mentioned, by utilising cloud services for example, provides the possibility of making data more accessible for FM practises and by automating processes, provides the benefit of being less person dependent and thus decrease resource demand. Additionally, by utilising BIM in combination with sensor data (IoT) can improve the decision-making process in energy management by more effectively monitor and optimise energy performance (Matarneh et al., 2019b), and could be further developed as the findings show, by incorporating ICT such as AI. As the FM industry is entering a new era of digitalisation (Bröchner et al., 2018), FM seems to be leaning towards a more data driven culture and thus transit towards being more associated with tech-companies, as the findings show. Moreover, FM companies will most likely benefit from putting emphasis on the organisational work and adjust accordingly to successfully manage the digitalisation process. This, as the statement of FM representative C highlighted the increased demand on FM managers in problem solving is connected to a more digitalised working process.

The literature shows that a possible implementation of BIM provides FM with visualisation of the physical asset and what is included. As these are the main value adding attributes according to Stride et al. (2019), result in a more efficient O&M of the building and installation objects, which is in accordance with the findings. However, as BIM seems to be lacking the ability to provide fully automated solutions and the capability to incorporate the emergence of intelligent data technologies, the future of utilising a Digital Twin in FM seems promising as stated by (Ozturk, 2021). As mentioned from the findings, a possible combination of providing mobile solutions with the connection to a Digital Twin for people working with O&M within the facility, would facilitate the utilisation of BIM in FM with providing continuous updates of changes made in the physical building and assure information and data quality connected to the asset.

5.3.2 Development of BIM in Facilities Management

Although three of the FM companies interviewed are currently implementing BIM in the O&M phase, the findings show that the use of BIM is still in its early stages and has the potential to be developed to further leverage FM practices. Two of the representatives emphasised the use of customised BIM, known as FIM and AIM, on various levels in current projects. According to the findings, these concepts have similarities, such as containing necessary data and information for FM regarding O&M and allowing for better visualisation and monitoring of installation objects.

Furthermore, FM representative D emphasised that the FIM primarily serves as a digital portal through which different FM systems can be connected and accessed more conveniently when performing O&M tasks. On the other hand, FM representative F emphasises the primary use of AIM as a single source of information that optimises the use of open-source formats such as IFC in FM to keep data quality assured and validated. The differences between the two concepts are not evident, though the FIM appears to be the equivalent vision of a Digital Twin based on the findings. Whereas the AIM seems to act more as a base or foundation of the digital representation of the building, where streaming data monitoring connected to energy performance for example, should be added to associate with the concept of a Digital Twin (Hosamo, 2022). Additionally, the simplified BIM model utilised in FM as mentioned by representative E, could be a similar concept to FIM and AIM due to the adaptation towards FM oriented information. The simplified BIM model seems to be a solution to combine the utilisation of object-oriented models (and how they relate to each other) with FM oriented data and information to improve FM operations. However, according to the findings, the simplified BIM model was not mentioned in relation to the concept of a Digital Twin. In contrast to Ozturk's (2021) concept of a more advanced virtual replica of a physical building, such as a Digital Twin, the simplified BIM model may be viewed as a basic digital model that is easier to develop and to use for FM practices. This shows that the FM companies that are currently implementing BIM have adopted the concept in the form of a customised version of BIM that has been adapted to fit the O&M needs of the specific organisation.

5.4 Challenges

5.4.1 BIM execution and Information management

Considering the responses of the FM companies participating in this study, all of them seem to have mentioned BIM execution and information management as barriers to implementing BIM in FM. Dixit et al. (2019) identify several issues related to this topic; these include unclear BIM workflow, incorrect information capture and failure to update BIM information, all of which have been noted by FM respondents. Both the interested and implementing groups have stated that a shift in traditional FM roles is required to cover the new responsibilities that integration of BIM will entail.

According to the FM interviewees in this study, the work of updating the BIM models for them to keep their value appears to be the most challenging process to adapt, which is something that has been noted by both Kassem et al. (2015) and Dixit et al. (2019). As FM representative B pointed out, it is critical to delegate this responsibility to someone in order to avoid the factors of unclear roles and responsibilities described by Becerik-Gerber (2011). Although the implementing group acknowledged the difficulty of updating the model, they also highlighted the importance of ensuring data quality and that the information added is correct. FM representative B contributed the challenge of updating the model to the traditional nature of the industry as well as the ongoing problem with updating paper drawings. This challenge is further strengthened by FM representative D's statement, which states that they are currently facing this challenge and lack proper procedures to deal with it. Thus, the results indicate that updating asset information may already pose an ongoing challenge within the industry and is not only related to BIM implementation.

Rather than a lack of client demand, as found by Dixit et al. (2019), the FM companies in the implementing group suggest that there is a lack of knowledge about how to request the data when they act as clients. Pinti et al. (2022) attributed the low adoption rate of BIM in FM to the lack of guidance and standards, which is apparent when looking at the results from this study. However, it is also evident that some of the companies in the implementing group, such as FM representatives D and F, are more concerned with how the BIM model should look. Nevertheless, when comparing the findings of Pinti et al. (2022) with the responses of the FM companies in this study, it is clear that there is a knowledge gap regarding BIM in FM. The results also support the findings presented by Poulitaival et al. (2016) that there is a lack of understanding of BIM processes and the software in FM. FM representatives B, C, and F all stated that their respective FM organisations have a lack of knowledge about how to navigate and use BIM tools.

5.4.2 Technological

According to the findings from the Consultants, it seems clear that there is an issue regarding BIM implementation and the utilisation of an BIM software in FM to manage it. Thus, the knowledge gap of operating and using BIM software and BIM expertise in FM is apparent, as mentioned by the consultants. This challenge is further strengthened by Pinti et al. (2022) and Poulitaival et al. (2016) who stated that FM lack an understanding of the BIM processes and software's, also, the inability to stay up-to-date with the constant development of BIM. A necessary part of BIM implementation in FM is to adopt current FM roles to new working methods connected to implementation of new processes and technologies, as mentioned by FM representative B & C, however, the conservative industry of FM and its cultural approach is one barrier to overcome. Due to slow adoption rates of newer technologies in the AEC/FM industry (Kivits et al., 2013) a concept such as BIM needs to be tested and evaluated, thus, BIM will most likely not be commonly used in O&M unless its value has been shown as stated by (Kassem et al., 2015).

Furthermore, the findings showed a clear barrier between current FM systems and BIM due to the lack of compatibility with BIM software, which is in line with the literature. FM representatives B&C highlighted their current use of traditional FM systems, and that one issue is that there are too many to handle and coordinate information efficiently. Thus, strengthen one of the main barriers to BIM implementation, as shown in the literature, due to the use of traditional systems in FM, such as CAFM, which leads to the rise of interoperability issues between FM systems and BIM (Matarneh et al., 2019a). The issue of interoperability seems to be the result of how FM practices were performed a couple of decades ago in accordance with the findings. FM practitioners apparently did not take interoperability between FM systems in consideration, or at least did not focus on this aspect, which today would have been shown valuable by making information sharing easier and data more accessible for future use such as rebuilds or renovations. BIM could be a solution to overcome this issue in the future in FM as Aziz et al. (2016) stated that the use of BIM, provides a platform where continuous access to updated information within the asset of building is available to not just FM, but during the whole life cycle of the project whether it is a new construction project or rebuild where other actors is involved. One way to overcome the challenge of interoperability issues, as the FM representative C and F stated, is by utilising an open-source system to be able to transfer BIM data without the issue regarding interoperability between different formats and systems. Furthermore, the common use of proprietary formats used in the AEC/FM industry is a major problem for BIM utilisation during the whole building lifecycle as the findings show. It seems that an important part of improving O&M processes with digital technologies such as BIM, is to not be locked to a specific format due to the building should last for 50-100 years. This means that for FM companies to be able to freely transfer data and information during the building lifecycle, utilisation of open-source solutions is necessary.

5.4.3 Cost & Legal

In contrast to Dixit et al. (2019), the findings of this study do not suggest that the cost and legal aspects of BIM implementation pose an immediate or significant challenge for an FM organisation. However, FM representative A stated that the cost of BIM implementation is a barrier. He further elaborated that his company would consider implementing BIM if they could gain some financial gain, such as cost savings or less time spent searching for information. Nevertheless, even if the cost and legal challenges were not as prevalent, they were still mentioned by some of the FM companies interviewed in this study.

According to the findings of this study, the most significant cost challenges are associated with unperceived cost benefits, which is one of the issues noted by Dixit et al. (2019) and Beach et al. (2017). Unlike the findings of Beach et al. (2017), this study indicates that the unperceived cost benefits are related to the benefits of using BIM rather than the flexibility of digital data storage. FM representative B also argued that it is critical not to set overly demanding targets for BIM utilisation, implying that it is essential to find the appropriate level of detail and LOD in the developed BIM models. Another concern that was mentioned by FM representative B concerning the cost challenge is the cost associated with updating the BIM model.

In terms of legal challenges, the findings of this study suggest that these issues include issues regarding ownership and responsibility for BIM data also contractual and compliance issues, which is similar to the findings of Dixit et al. (2019). Only FM representative B mentioned legal challenges in the interested group, emphasising that the ownership of the data was the most significant issue. However, the legal challenge in the implementing group was moving away from paper drawings as legal documents, which was only mentioned by FM representative F.

5.5 Sustainability

The topic of sustainability was not a frequently mentioned area in the interviews, although both the interested group and FM company F had input on varying levels regarding sustainability and BIM. As the findings show from the interested group, FM companies today seem to focus on reducing energy costs which appears to be one of the major challenges in the industry. In the same notion, the literature generally lacked information regarding how BIM could facilitate sustainability. However, some of the findings indicated that BIM could be utilised to facilitate energy management in O&M (Matarneh et al., 2019b) and thus facilitate decision making connected to energy savings and consumption.

Furthermore, according to the interested group, one advantage of implementing ICT, such as IoT sensors in facilities, is having access to automatically generated and real-time energy data consumption as a foundation for ESG reporting. As a result, they can better monitor and meet the requirements for "green loans" from banks, facilitating both sustainability and economic aspects. Moreover, connected to the literature, FM is entering a new era of digitalisation where ICT solutions and technological improvements such as IoT enable and facilitate sustainable FM practices (Bröchner et al., 2018).

All of the interviewees from FM company F shared their specific thoughts around how BIM could facilitate sustainability in O&M, which could mainly be the cause why their company seemed to focus more on an existing building with rebuilds and renovations rather than new production projects. Most of the interviewees mentioned that BIM could be used to facilitate reuse and traceability in theory. More specifically, where an effective reuse process could be maintained due to BIM providing better monitoring of the type of products and materials that are used in the building if it is updated continuously. Also, connected to BIM and the concept of information sharing and data exchange in the literature, the utilisation of standards such as COBie and IFC promotes reuse in the AEC/FM industry, as mentioned by Ozturk (2020). Furthermore, as mentioned in the interviews, traceability is most likely facilitated by utilising BIM due to easy access to the rich database of gathered information regarding products and materials that BIM provides.

5.6 Future work

Ultimately, the findings of this master's thesis are based on the Swedish FM market and may not be entirely consistent with the international literature cited in the theoretical framework. Nonetheless, the findings of this study are only an indication of the difficulties that the Swedish FM organisations may face when implementing BIM. As a result, future work could include surveying FM companies of various sizes and market values to determine whether the challenges presented in this study apply to all FM companies. Because this master's thesis is researching potential challenges that FM firms may face rather than proposing a framework for overcoming them, another possible future project would be to research (perform a Case study) on an FM company that is facing these challenges and propose or develop a framework to overcome them.

6 Conclusion

The objective of this research was to investigate and gain an understanding of the underlying barriers to implementing BIM in facilities management by directly interviewing FM practitioners and obtaining their perspectives on this challenge. This, in order to gain a better understanding of the underlying causes of BIM's slow adoption in FM. In addition, this thesis will help to fill a knowledge gap about BIM in FM by discussing its benefits and potential implications for the field. Thus, the following questions were used to guide the study:

1. What are the most common challenges experienced by FM practitioners of BIM implementation in their work?
2. What is the root cause of these challenges?
3. How could the concept of BIM be further developed to fit the needs of FM?

The results showed that most of the FM companies in this study mentioned BIM execution and information management as the most frequently encountered challenges in BIM integration, followed by technological challenges. In contrast to the literature on cost and legal challenges, the findings of this study do not indicate that the cost and legal aspects of BIM implementation pose an immediate or significant challenge for an FM organisation.

The root causes of BIM execution and information management challenges are information requirements and keeping the model up to date, which leads to delegating responsibility and creating new roles. In terms of technological challenges, the root causes appear to be an excess of BIM software, the proprietary format of BIM, and the legacy of old FM systems. According to the findings of this study, the most significant cost challenges are related to unperceived cost benefits. In terms of legal challenges, the study's findings indicate that these issues include ownership and responsibility for BIM data, as well as contractual and compliance issues.

To answer the third research question, FM would benefit from utilising BIM as a platform to gather and facilitate access to FM systems and data, however it is apparent that each FM organisation should develop a customised or tailored version of BIM to fit their specific organisation needs to obtain maximum value. Although to facilitate the use of BIM in FM, there is a need for BIM standards to facilitate requirements, development of new roles or adoption of traditional FM roles to fit the new responsibilities regarding digitalisation in FM, alongside utilisation of open-source solutions for BIM software.

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8 Appendences

8.1 Appendix 1 – Translated Interview guide for consultants

- What is your company's area of interest?
- What is your position in the company?
- For how long have you been working in the AEC/FM field?
- How would you define the BIM concept?
- Do you have prior experience working with FM?
- Is it common to collaborate with FM personnel?
- What types of information are important to FM personnel and could be facilitated by BIM?
- What are the challenges regarding BIM implementation in FM?

8.2 Appendix 2 – Translated Interview guide for FM companies

- What is your company's area of interest?
- What is your position in the company?
- For how long have you been working in the FM field?
- To what extent has your digitalisation work been integrated in your daily operations?
- What type of information is of interest to you in FM?
- How much of your information is digitalised respectively analogue?
- What type of information systems do you use in in FM?
- What are your prospects regarding digitalisation in FM?
- What comes to mind when you hear the term BIM?
- How common is the use of BIM in your daily operations?
- What kind of advantages could BIM bring to your operations?
- What are the challenges with implementation of BIM in your opinion?

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