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Digital Asset Management in the Real Estate Sector

Enablers and barriers for collecting and maintaining digital information during a building's life cycle

Master's thesis in Design and Construction Project Management

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MASTER'S THESIS ACEX30

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ABSTRACT

With an aim to investigate how different companies within the real estate sector approach and organize digital asset management in the use and operational phase of a building's life cycle. Further, with an aim to investigate what barriers and enablers companies are facing in relation to activity, technology, information, and processes, to further increase monetary efficacy and growth a comparative case study is conducted. Three case companies within the real estate sector have been selected. Data has been collected through interviews. The results indicate that the companies have a common understanding that there is a digital change process that is needed to be adapted to be able to work more efficiently. The analyzed companies have chosen different strategies towards digital asset management mainly due to contextual factors. All companies have created enabled factors according to people and roles working with digital asset management. Unclear responsibilities and roles have been identified as barriers, together with a high level of autonomy and decentralization. The faith in technological evolution is strong and large investments in digital tools and systems have been done by the different organizations.

There is also a common understanding that an operational information model with a focus on need-to-have information to be manageable. Old habits and tradition is becoming a barrier since the current practice is influencing the low reliability and quality of the digital assets. Since smaller projects are not allowing for information and knowledge to be transferred properly within the companies, new processes need to be developed. Processes enhancing life cycle quality and reliability in the digital asset management process needs to be further developed together with a new technological solution such as an errand system.

Key words: Digital Asset Management, Information Processes, Digital Twin, BIM-management

Digital tillgångshantering i fastighetssektorn

Möjligheter och hinder för att samla in och underhålla digital information under en byggnads livscykel

Examensarbete inom masterprogrammet Design and Construction Project Management

SIMON STÅHLKRANTZ

Institutionen för arkitektur och samhällsbyggnadsteknik
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SAMMANFATTNING

I syfte att undersöka hur olika företag inom fastighetssektorn närmar sig och organiserar digital tillgångsförvaltning i användnings- och driftsfasen av byggnadens livscykel och vilka hinder och möjligheter de står inför i relation till aktivitet, teknik, information och processer. För att ytterligare öka den monetära effektiviteten och tillväxten har en komperativ fallstudie genomförts. Tre företag inom fastighetssektorn har valts ut och data har samlats in genom intervjuer. Resultaten visar att företagen har en gemensam förståelse för att det finns en digital förändringsprocess som behövs för att kunna anpassa sig och för att kunna arbeta mer effektivt. De analyserade företagen har valt olika strategier för digital tillgångsförvaltning främst på grund av kontextuella faktorer. Alla företag har skapat möjliggörande faktorer där olika personer och roller arbetar med digital tillgångsförvaltning. Oklara ansvarsområden och roller har identifierats som hinder, tillsammans med hög nivå av autonomi och decentralisering. Tilltron till teknisk utveckling är stark och stora investeringar i digitala verktyg och system har gjorts av de olika organizationerna. Det finns också en gemensam uppfattning kring att en operationell informationsmodell med fokus på den allra viktigaste informationen. Gamla vanor och tradition kan utgöra hinder, eftersom den nuvarande metoder påverkar de digitala tillgångarnas låga tillförlitlighet och kvalitet. Eftersom mindre projekt inte tillåter att information och kunskap överförs ordentligt inom företagen måste nya processer utvecklas. Processer som förbättrar livscykelkvaliteten och tillförlitligheten i den digitala tillgångsförvaltningsprocessen behöver utvecklas vidare tillsammans med nya tekniska lösningar, såsom ett ärende-system.

Nyckelord: Digital tillgångsförvaltning, informationsprocesser, digitala tvillingar, BIM-förvaltning

Contents

Preface

This thesis has been conducted at the Department of Architecture and Civil Engineering, Division of Construction Management, at Chalmers University of Technology, Gothenburg, Sweden. Representatives from Zynka Group AB, Gothenburg, Sweden, have offered supervision and guidance throughout the study. I would gratefully like to thank:

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Gothenburg, 2021.
Simon Ståhlkrantz

1 INTRODUCTION

1.1 BACKGROUND AND PROBLEM DESCRIPTION

During the last decades, there has been a rapid digital transformation in society. In the latest European Union report on the Digital Economy and Society Index (DESI), which measures the digital integration of EU member states, Sweden stands out as the second most influential country when measuring digital intensity and integration of enterprises (European Commission, 2020). According to McKinsey (2017), there is a large economical value embedded in digitizing the different market sectors in Sweden. Through the implementation of automatization and advanced data analytics, and by increasing connectivity, cloud services, and communication, a potential annual value stream of 850-1400 billion SEK, or up to 25% of the Swedish GDP, can be generated from the year 2025. Realizing the potential value of these new technologies, requires well-defined eco-systems and digital infrastructure, together with a collaborative environment between different actors.

The digital transformation is also reflected in the real estate sector. Digital tools and mobility have already changed how we utilize our buildings. Rising demand for more flexible workplaces allows for more efficient space utilization. Our new digital integrated lifestyle also creates a demand for more connected housing solutions. These factors, together with many others, accelerates a disruptive change in business logic, which the real estate sector needs to adapt to. Property owners have also started to see the benefits of Property technology (PropTech), which is creating and integrating a new digital environment in our buildings. Together with increasing complexity and demand for technical functionality, this creates a large stream of information that is needed to be handled by the property owner (Fastighetsägarna, 2018).

Today, technologies such as Building Information Modeling (BIM), Digital Twins, and different management systems are replacing old ways of information handling within the organizations of asset owners (Atkin & Bildsten, 2017). The technologies give the property owners the ability to not only acquire a physical building, but also a digital representation of it, allowing for data-driven and strategic decision making, as well as a solution for efficient space management, monitoring, and maintenance planning (Atkin & Brooks, 2015). However, asset owners in the real estate sector often underestimate the value, advantages, and possibilities of these new information models. Thus, there are potential savings in the asset management process (Bolshakov et al., 2020). Further, the BIM model and Digital Twin is often a residual product from the design and construction phase of a new development, where stakeholders already have started to gain large benefits from the technology. Thus, there is also an increasing interest from property owners, with a property portfolio of existing buildings, who wants to gain the benefits from the digital evolvement (Dejaco et al., 2020; Nyvlt, 2020), but processes for collecting, maintaining, and updating the information in later stages of the building's life cycle, have not yet been defined to a great extent.

1.2 PURPOSE

In the use and operational phase of a building's life cycle, the digital asset management process is important for keeping the high quality and reliability of digital assets. The purpose of this study is firstly to explore and analyze how real estate owners approach and organize digital assets management in the use and operational phase. Secondly, the purpose is to identify what barriers and enablers property owners are facing in relation to activity, technology, information, and processes. The purpose of this study is to contribute to a deeper understanding and a knowledge transfer of more efficient digital asset management. This thesis will also contribute towards a more sustainable built environment by addressing the need for efficient use of resources.

1.3 OBJECTIVES AND RESEARCH QUESTION

The objective of the study is to investigate how different companies in the real estate sector approach and organize digital asset management in the use and operational phase of a building's life cycle, and what barriers and enablers they are facing in relation to activity, technology, information, and processes, to further increase monetary efficacy and growth. The research questions are as follows:

- How do property owners approach and organize digital asset management in the use and operational phase of a building's life cycle?
- Which enablers and barriers are property owners facing in the strive of having high quality and reliability of their digital assets during the use and operational phase of a building's life cycle?

1.4 LIMITATIONS

In this study, real estate owners´ approach to and how they organize digital assets management and what barriers and enablers they are facing are explored and analyzed. A delimitation has been made to one of the later stages of a building's life cycle, the use and operational phase. The result and analysis are based on empirical data from three case companies. Limitations can be found due to the case companies' organizational size and unique characteristics, the number of case companies and respondents, and the interviewees´ roles within the companies.

1.5 DISPOSITION

In the next, and second chapter, the theoretical framework of the study is outlined. In chapter three, the methodology guiding the study is presented, together with a description of the collection and sampling of empirical data and how the study was conducted. In the following chapter, the three case companies are presented, and in chapter five, the results of the study are presented, followed by an analysis and a discussion in chapter six. Finally, the last chapter includes a conclusion.

2 THEORETICAL FRAMEWORK

This chapter includes the theoretical framework which creates the context and background of the study. Firstly, real estate is explained in the terms of an asset class, explaining the main values related. Secondly, a building´s life cycle is described, followed by a presentation of the role of asset management, showing the importance of creating value within a building's lifecycle. Thirdly, digital asset management is outlined, creating a deeper understanding of which activities, technologies, information, and processes are acting as enabling and barring factors in today´s practice of building asset management.

2.1 Real estate as an asset class

Properties are classified as real, fixed, or tangible assets, and their capital represents a big portion of the world equity market. With growing recognition of the role that real estate has as an asset class, it has become a strategically preferred strategy, to include properties in a diversified multi-asset portfolio (Lekander, 2015; Sternik & Teleshev, 2018). The Swedish real estate market is composed of a mix of private and public actors, with different scope and aim in their business activities. In Sweden, there is a domestic quantity of 135 000 multi-family residential buildings, including 2 388 000 apartments, where approximately 40% are owned by individuals in condominiums, 30% by private real estate companies, and 30% by the public housing companies (Fastighetsägarna, 2021). Further, commercial real estate, designated for office and retailing, is dominated by large asset owners, where the top ten largest actors in 2008 had a portfolio of 2 to 3,5 million m^2 of commercial space (Nordstrand, 2008). The Swedish Financial Supervisory Authority (2019) defines *Commercial real estate* as properties, which the primary use of space, is designated to generate income through leasing. Therefore, this definition includes offices, retail, manufactory, logistics, hotels, housing, and community properties (healthcare, education, and welfare). *Commercial residential properties* are further defined as properties including three or more units, typically apartments. The main business idea of commercial real estate companies is to over time increase the rental income of the property portfolio, the amount of rented space, and rent income, as simultaneously keeping the operating- and maintenance cost low, resulting in an increased operating net profit (Finansinspektionen, 2019).

Traditionally, the view of value creation of real estate has been limited to include only the tangible assets, where primarily, the physical property itself has been seen as the delivered product to the user. In recent years, this view has had a change of scope, to where tangible and intangible assets are integrated, with the goal to deliver a complete service and to fill a need of the user. This change can be theorized as a change from a traditional *goods logic* to a *service-dominant logic*. Skålén (2018) describes goods logic as to where value is created internally in organizations. Using a building as an example, it is succeeding becoming more and more valuable in the different stages of a construction phase, where it upon its completion is bought by the customer and exchanged for money. This implies that the value of the building is only measured in monetary terms. Service-dominant logic differs from goods logic by the means that the value is created when a good, or a service, is used by the customer. This logic implicates that a building only can generate value when it is used, for example as an accommodation, workplace, or learning institution. Applying this new logic in the real estate business allows alternative value streams, resource integration, and co-creation of value. Further, Re Cecconi et al. (2020) explains that the change towards a new

business logic has been allowed through a substantially more accelerated digital environment, implicating that a lot of properties are producing more and more information during their life cycle, which allows for information to be used throughout the property's operational phase. This creates an opportunity for new ways of modeling and processes for the management of information, to achieve better performance of an asset.

2.2 Integration of a life cycle mindset within the AECO-sector

The AECO-sector (Architecture, Engineering, Construction, and Operation) is one of the largest contributors to global warming, carbon emissions, and environmental degradation, resulting in a substantial impact of 19% of Sweden's total Co2 emissions in 2017 (Boverket, 2020). There is a strong need to reduce the environmental impact of the sector and to adapt to a whole-system and life cycle thinking, as well as to promote innovation. The life cycle mindset needs to be acknowledged at a large scale of supply chains down to a building level. Further, the customers within the sector are starting to demand environmentally friendly products and processes which enhances innovative strategies, long-term perspectives, and better decision-making (Dalla Valle, 2021).

The included phases of the building's life cycle are illustrated in chronological order in Figure 2.1. A building' life cycle is initiated with a design phase, followed by a construction phase which realizes the design. Further, the completed building is delivered to the asset owner. During the use phase the asset is being utilized for the intended operation, managed, and maintained. When a building has reached the technical functionalities life span, the end of life is reached and either disposed of or reused. The design and construction of a new building is both capital and resource-demanding, but since the operational phase extends over a much longer period of time, the costs- and resources used in the building's operational phase is often far more extensive, when viewed through a life cycle perspective (Nordstrand, 2008; Peng, 2016; Pomè et al., 2021). The scope of this study includes collecting, maintaining, and updating the information of digital asset management in the later stages of a building's life cycle, more particularly in the building use phase (Nordstrand, 2008).

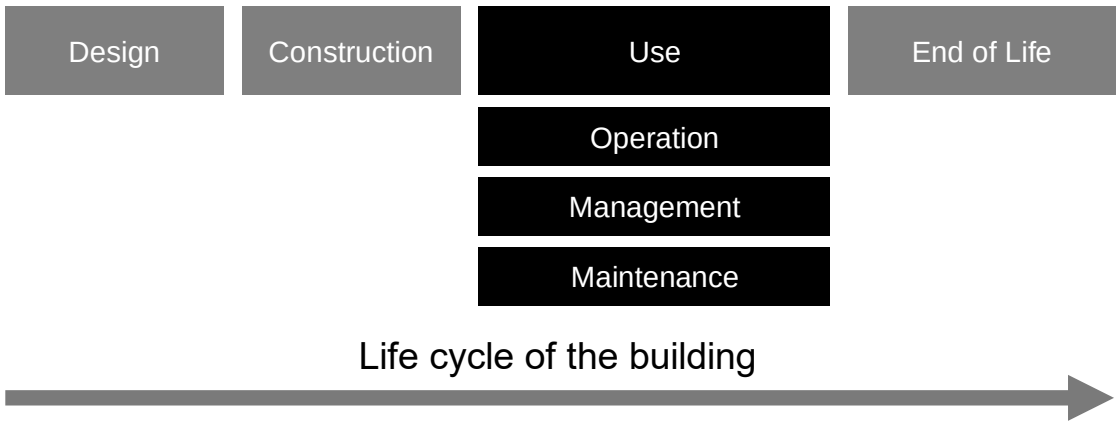


Figure 2.1: The stages of the building life cycle (Ganter & Lützkendorf, 2019).

2.3 Digital asset management in the real estate sector

In the last decades, Facility Management (FM) has had a rapid growth of interest, where the traditional roles of managing buildings have turned into a professional real estate business (Nordstrand, 2008). FM, which is also mentioned as Asset Management of buildings, is defined by the International Facility Management Association, IFMA, (2021) as a profession that encompasses multiple disciplines to ensure the functionality of the built environment by integrating people, place, process, and technology, see Figure 2.2 (IFMA, 2021). This definition of FM is seeing the practice as a holistic discipline where multiple factors are involved.

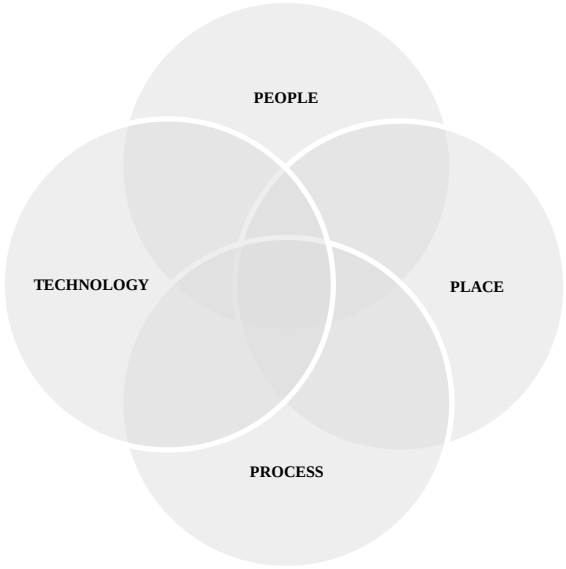


Figure 2.2: IFMA (2021) definition of FM, people, place, process & Technology.

Another definition of asset and facilities management is exemplified by Saiful Bahri et al. (2019), as "A strategic Management towards preservation of asset and facilities value through its life cycle" (p. 564). Regardless of the definition used, maintenance of physical assets is one of the largest operational expenditures (OPEX) in many organizations, independent of size and sector. The significations of OPEXs are often large due to insufficient space utilization, high energy consumption and, or unreliability in maintenance. Kincaid (1994) explains that facility management can be seen as an integrated function in an organization, and by further defining three main characteristics of this function. Firstly, FM is acknowledged as a support service in an organization. Secondly, for FM to generate value, it needs to sync strategical, tactical, and operational management with other activities of the organization. Thirdly, FM needs to have good knowledge of the facilities, and management processes, to be able to support an organization efficiently. Further, since FM services is a supporting actor, often outsourced, allowing for a higher focus on core businesses, it needs to show value either directly or indirectly, as well as in both tangible and intangible factors (Atkin & Bildsten, 2017).

In the management process of Corporate real estate (CRE), OPEXs are often seen as expenditures that do not go beyond the physical asset itself, and where the strategical

decision-making is only related to investment costs. Whilst, a more accurate yet more forward-thinking view, is to say that the asset manager's role, is to add value to the organization through integration of FM, strategic real estate, and property management (Carbonari et al., 2018). The core activities of real estate asset managers, in corporate settings, can be explained as procuring, develop, manage, and sell real estate.

FM is often seen as a reactive practice, acting on a moment's urgency. As an FM operator dealing with errors regarding the utilizer's comfort level, maintenance problem, or service of the building. Reactive management within the sector creates a lot of struggles, it does not allow for enough planning and risk prevention. Proactive management is often a preferred way of working. It allows the FM to avoid crises and make better use of resources (Teicholz, 2001).

Drawing on IFMA (2021) definition of FM, people, place, process, and technology, in this study the digital asset management have further been categorized into four different parts, activity, technology, information and processes see Figure 2.3. Activity assesses the different activities included in the digital asset management process, such as the facility management role in the building's life cycle, key activities involved, and current barriers to the practice.The technology assesses the current tools used for digital asset management and executing the activities in an efficient manner, including digital twins as a concept, Building Information Modeling (BIM), Geographical Information Systems (GIS), and the Internet of Things (IoT). Information is assessed as the backstitching of the digital asset management process, where building information is explained and concretized, as which information is needed for the activity, and in which technology it is held. Lastly, processes include the current practices of working with digital asset management, standards implemented, and its barriers.

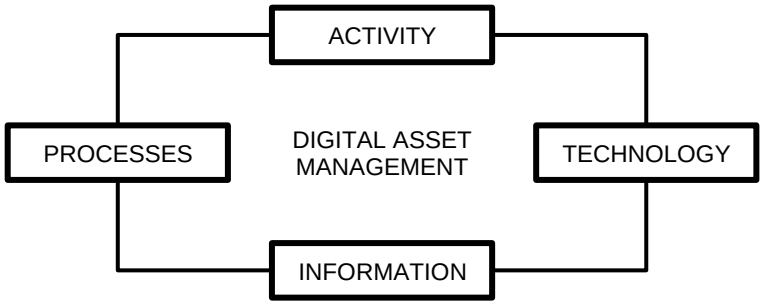


Figure 2.3: Theoretical framework - Digital Asset Management

In the following sections each of these aspects are outlined in more detail.

2.3.1 Activity

This section starts with a presentation of the facility management's role in a building´s lifecycle, followed by an outline of space and energy management as key activities in digital asseet management.

2.3.1.1 Space management

One important function that a building asset manager has to accomplish, is to have efficient use of resources. Space management is the activity and process of determining which space is needed and its requirements, while identifying deficiencies, allocating space available in an efficient way, monitoring the use of space, and overall managing and offering service to the space utilizer. Efficient space management requires well-

defined and consistent processes for storing, querying, and updating the geometrical and non-geometrical information (Saiful Bahri et al., 2019). Space management includes making the physical space available as cost-effective as possible. For a resource-efficient use of space utilization, information about space also needs to be accessible and acknowledged by the asset manager. Having the right knowledge about the space-utilization in a portofolio makes it possible for measuring the costs for servicing, leasing contracts, and energy-saving measures. Further, optimizing the occupancy and activities that are related to certain spaces is a crucial factor in the space management process (Atkin & Brooks, 2015). A crucial goal for the asset owner is to minimize the downtime of the assets, it is therefore highly important for the property management to have tools for making efficient workspaces for planning and moving costs (Bolshakov et al., 2020).

2.3.1.2 Energy management

Buildings are responsible for high energy consumption during the operational phase. Lowering the energy consumption in the real estate sector could contribute towards a sustainable economy (Becerik-Gerber et al., 2012). It is of high interest for a property owner to focus on the energy performance of their building, since it is strongly related to environmental as well as monetary value. By utilizing historic energy performance data, costs related to the energy performance can be foreseen. Also, it allows for knowledge to be created allowing for energy conserving measures to be done, as well as creating stability in the asset management process (Atkin & Brooks, 2015).

2.3.1.3 Maintenance

Nordstrand (2008) describes the fundamentals and relationship between different types of maintenance of physical assets, represented in Figure 2.4, where maintenance can be categorized by two principles, planned and remedial maintenance. *Planned maintenance* is defined as a preventional measure, which includes measures that minimize the risk of damaging the building and ongoing operations in the facility. *Remedial maintenance* seeks to include measures that solve already existing errors or damages. Further, planned maintenance can be divided into sub-categories of *operational maintenance*, including measures that are done within a periodic time frame of 2 years or less, or *long-term planned maintenance* including measures done in a frequency of 2 years, or more. Measures included in the long-term planned maintenance are such as redoing of surface layers, roofing, or change of air handling units (AHU). The *operational maintenance*, is further divided into *Periodic Needed maintenance*, including measures such as change of filters and belts for the AHU, or larger inspections, alongside others. *Condition Based Maintenance* are measure that are done by inspection and are dependent on the current need for maintenance.

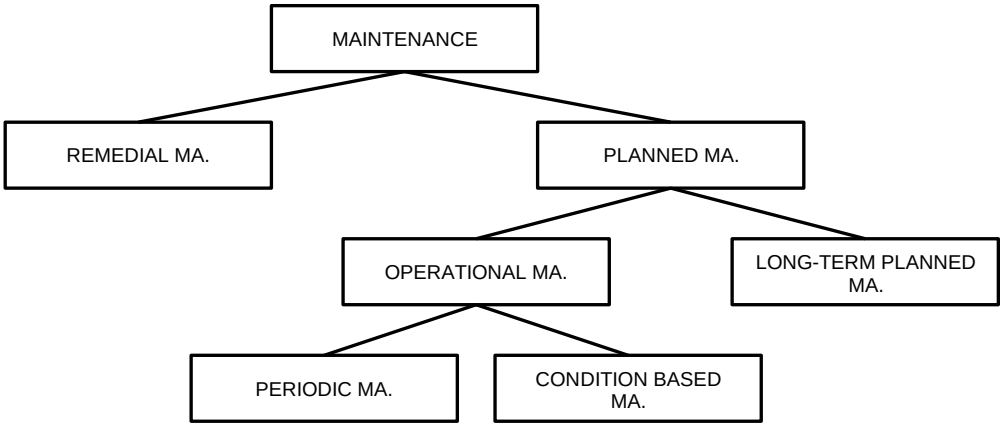


Figure 2.4: Maintenance of physical assets.

2.3.2 Technology

As a second aspect of digital assessment management, technology assesses the tools used to execute the activities effectively. Digital Twin, Building Information Modelling, Geographical information system, Reality capture, Internet of Things, and Management Systems are presented below, as digital technological tools for making FM more efficient. Finally, Roger´s innovation curve is presented, as an example of the spread of an innovation in an organization.

2.3.2.1 Digital Twin

The phenomenon of a digital twin has a different definition depending on its use case. The overall vision is that every physical object should have a dynamic software model of itself. In the scope of this study, a digital twin is defined as the virtual representation of a physical object or system across its lifecycle, which is also the same definition used by IBM (2021). By defining a digital twin as a phenomenon, rather than a technology, keeps the door open for a more holistic research approach, where the digital twin combines different data types to develop a 3D model and further enhances the possibilities for strategic decision-making. A digital twin in the use case of real estate has the possibility to facilitate real-time data access, visualization, and marketing, creating and updating digital assets, checking maintainability, space management, and emergency management, energy management, and many other use-cases. A digital twin aims to dynamically connect and integrate the asset owner with the process of its creation in an early stage, efficiently manage the changes in coherence with the characterises of the physical asset throughout the building's life cycle. A large change in the consumer behavior is that the asset owner gets a possibility to get knowledge about the consumer properties of an asset, and can foresee the technical and economical parameters of the asset, due to how the building is behaving, allowing for proactive facility management (Bolshakov et al., 2020).

A digital twin can be just as smart as any other device, it is dependent on the sensitivity, connectivity, and interactivity in the relationship of a digital and physical asset. In a smart and well-achieving digital representation, the building can sense any alteration, predict responses and interact together with the utilizer to enhance the response efficiently. This requires the digital twin to have well-integrated and chosen sensor nodes, and further use algorithms for behavior analysis (Poli et al., 2020).

2.3.2.2 Building Information modelling

Building Information Modeling (BIM) can be explained as a digital representation of a building, where views and data can both be stored, extracted, and analyzed to generate information that can be used through the different stages of a building's life cycle. BIM is to be recognized as a vital technology for the evolvement of the Architecture, Engineering, Construction, and Owner sector (AECO). It is said, that many of the recognized problems that the construction industry is facing can be solved by digitalization and with the implementation of BIM (Carbonari et al., 2018). BIM has made it possible for resource efficiency in the design, construction, and operation of a building. It is further defined by Gao & Pishdad-Bozorgi (2019) as an "improved planning, design, construction, operation, and maintenance process using a standardized machine-readable information model for each facility, new or old, which contains all appropriate information created or gathered about that facility in a format useable by all throughout its lifecycle" (p.227).

BIM has in the last decade become more widely used within the AECO-sector. Whilst BIM has a strong influence in the design and production phase of a building, the operational applications have been less explored. Updating design models with as-built information, and the lacking of operational input during the design and construction process, are some of the challenges when trying to implement BIM in the facility management process. Other challenges in the implementation is the handover from project delivers, where the information often is inadequate or inaccurate, unvalidated, and not suited for the operational stage. However, in the case of a newly built construction project, it is most likely the premisses for achieving a well-developed BIM model when compared to developing a model for an existing building, thus the major benefits and opportunities can be gained from implementing BIM in the current building stock (Carbonari et al., 2018).

2.3.2.3 Geographical Information Systems

Geographical information system (GIS) is referred to as a digital system that is designed to capture, store, manipulate, analyze, manage, present and disseminate spatial or geographical data. GIS combines spatial data with attributes for decision making. GIS is mainly used for development, environmental applications, security, business development, taxation, asset management, and other tasks that require the counterplay between the spatial and attributable relationship. As a typical GIS database is based upon spatial and non-spatial data, also referred to as geometrical and non-geometrical data, geometrical data is the data that shows the physical and space variables, where the non-geometrical data shows the qualitative or quantitative value. Geometrical data is in the application of GIS further divided into two categories which are vector data models and raster data models. Where vector data is represented in three types, points, lines, and polygons consisting of coordinate values. Whilst raster data models are based on regularly spaced grids consisting of rows and columns of pixels, using a single value to represent a multiplicity of parameters (Saiful Bahri et al., 2019).

2.3.2.4 Reality capture

A point cloud is gathered from the methodology of 3D-scanning and the use of LiDAR-surveying (Light Detection and Ranging), the technology allows for a fast, precise, and automatic way to measure millions of points to the exact location, generating a point-cloud. The point cloud further consists of millions of points which are acquired by measuring the response time between the LiDAR-surveying tool and the reflecting

object, the distance of the physical object can be measured. Further, by rotating at a 360-degree angle, whilst measuring distance points, a point cloud is created where each point is given its coordinate. A point cloud is often combined with a photogeometrical representation, which utilizes photos to create a digital representation of the physical object. There are similarities to LiDAR-surveying since the tools used often have the option to also utilize photometrical scanning. A photometrical 3D-scanning allows for a more colorized and visualized representation of an object, by combining photographs taken in the sphere (Mahdjoubi et al., 2013; Pöchtrager et al., 2017).

2.3.2.5 Internet of Things

Property technology has been increasingly noticed in recent years, the Internet of Things (IoT) and big data are the integration of several technologies to increase connectivity and provide smart services in the built environment. By implementing sensors into a building, improvements in the operation and management of the building can be effective. In the case of management of public spaces, such as in a university setting, sensors can help to provide data about occupancy-level in different spaces, and further provide knowledge for strategic space and energy management (Azizi et al., 2020). Generating sensor data that is related to Co2, temperature, airflow, lighting and even acoustics in properties is further a way for property owners to improve the proactive measures taken within the FM sector (Koch et al., 2019).

2.3.2.6 Integrated Workplace Management Systems

IT has an important role in the acquirement and codification of knowledge within an organization. Management systems can store large amounts of information and knowledge, allowing for easy distribution and reuse. Building assets is operated in three management levels: Strategic, tactical, and operational level, and it is of great importance that the three management levels have clear communication and a common system that allows for easy information transfer between the management levels. There are many different categories of IT systems and technologies being utilized in the real estate sector, for example, workflow systems is used for digitizing the workflows/ business processes concerning facility management, such as computerized management systems (CMMS), computer-aided facilities management (CAFM), integrated workplace management system (IWMS) and enterprise resource planning ERP (Maslesa & Jensen, 2019). Bjälnäes (2016) explains in a report for Sweden's municipality and county council that IWMS is a system that is allowing for:

- More efficient work processes.
- Real-time reports of benchmarks.
- A centralized and continuous planning for businesses.
- Increased availability and streamlining of the operational work.
- Identifying poor performing and unutilized assets and resources.
- Automation of a report system to internal and external stakeholders.
- Improved budget control and lower life cycle costs.

Faciliate is a well known IWMS-system based on the previous system known as Landlord. It is provided by Service Works Global and is a system that connects traditional real estate management processes with workplace service, graphic visualization and document management that support companies' processes in a common solution. With an aim to provide an easy easy-to-use interface for all different professional roles. In the IWMS-system an installation database function, as well as a

models/drawing viewer and an errand system is available (Service Works Global, 2021).

Bjälnäes (2016) also explains which factor organizations that are procuring and implementing a new IWMS-system needs to take into consideration. A new IWMS-system requires that a company's information management works both before and after the implementation. It is further important that the company have a good idea of which information structure, quality, updating, and other processes which the current information flow requires. To be able to handle the large information flow of drawings, models, contracts, and reports a standardized and structured way of working is needed.

2.3.2.7 The Innovation Curve

Rogers et al. (2019) seek to explain how ideas and technologies spread by looking at how, why, and at which pace actors adapt to an innovation. Within the theory of diffusion of innovation, the technological implementation can further be categorized in the terms of in which order organizations are taking a stance in the digital evolvement. Figure 2.5 illustrates how 2.5% of the actors are considered *Innovators*. The innovators are persons or organizations that are willing to take risks and are being a driving force due to high social status and financial liquidity. Resources help an innovator to absorb failures and enhances risk-taking. *The early adopters* consist of 13.5%, and are the adopters with the highest opinion leadership, combined with a higher social status, financial liquidity, and advanced education. The early adopters are more discreet than innovators in the adaption of new technology. The *Early Majority* consists of 34%, and adopt the innovation after the innovators and early adopters and have a majority of actors above average social status and position of opinion leadership. The *late majority* is the next group to adapt an innovation. The late majority is often skeptical, with lower financial liquidity and social status, combined with a low opinion leadership. Lastly, 16% consists of *Laggards,* which is the last to adopt an innovation. With a bare minimum of opinion leadership, the laggards are focused on traditions, have lower financial liquidity and the lowest social status, and are also older among adopters and are often working in a more private setting.

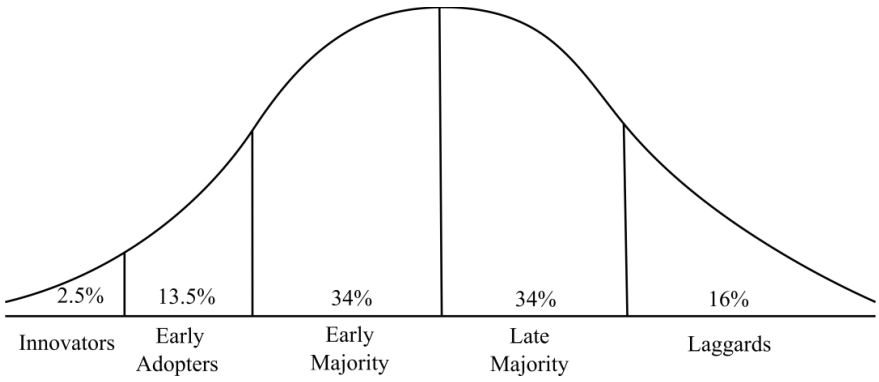


Figure 2.5: The Diffusion of Innovation theory (Rogers et al., 2019) .

Four main elements influence the spread of a new idea or innovation: innovation as such, the communication channels, time, and the social system. Innovation must be widely accepted to establish itself and there is a point of critical mass along the way. Individuals experience five different phases on the path to accepting an innovation:

knowledge, conviction, decision, implementation, and confirmation (Rogers et al., 2019).

2.3.3 Information

One of the most critical issues in the management of the built environment is explained as the collection, management, and use of information. Having the accessible and correct information is recognized as a vital factor for successful Real Estate Management, and is the essential prerequisite for supporting strategic decision-making (Dejaco et al., 2020; Ganter & Lützkendorf, 2019). Thus, operators in the real estate sector deals with a high amount of data, which is often stored in outdated and unrelated data formats, such as digital 2D drawings, PDF files, spreadsheets, or even physical papers (Carbonari et al., 2018; Dejaco et al., 2020). In parallel with the increase value that lays in information, the risk of dealing with incomplete or false information is rising. Building information is to be stored over a long period of time, and is partially getting changes due to renovations, additions, and new data formats. (Ganter & Lützkendorf, 2019).

The process of information communication is a vital factor during the operational stages of a building's life cycle. For a property owner to take full advantage of the current and future technologies related to digital building assets, it is of great importance that the information models such as a digital twin are in the hands of the right stakeholder, primarily the owner of the asset. There are often intellectual property rights stated by the consulting and engineering companies which do not allow for transparency and easy access to information such as 3D models used in projects. Further, as in the case of an building project, the 3D model is getting more and more informative and is transforming from a volume model to a as-built model. The parties involved in the construction project are in the end sharing the intellectual ownership of the model (EFCA, 2018).

2.3.3.1 Information flow within a buildings life cycle

The integration and relationship between the physical and information assets needs to be defined for the building, making sure that it operates correctly, and gives the service that it is intended for, for the rest of the life cycle. Responsible actors of Information asset management need to have knowledge and understanding of which information is necessary, and to which extent, for the FM functions to operate and maintain the facility. Too little information about a facility makes the management uninformed, whilst a too large pool and flow of information, is unmanageable and counteractive (Atkin & Brooks, 2015). An example of information flow within a building's life cycle is illustrated in Figure 2.6. In the illustration, the information is correlated to the relationship of supply and demand, together with which stakeholders are playing each role. As an example, the construction documentation including specifications of material is also used in the buildings ending phase and therefore needs to be continuously updated within the building's operational phase. Important to notice is that each stakeholder can be on both the supplying and demanding side of the model, dependent on the occasion.

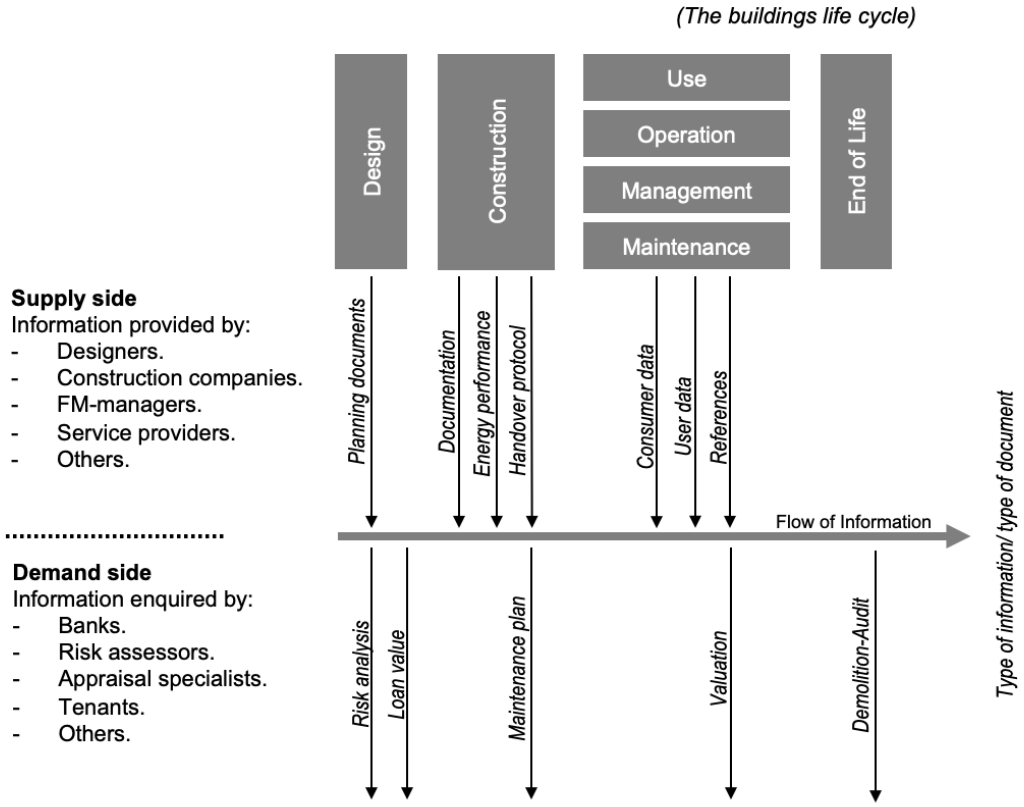


Figure 2.6: The flow of information in a building's life cycle (Ganter & Lützkendorf, 2019).

Ganter & Lützkendorf (2019) also explains that there is a trend towards more requirements of information management in the different stages of a building's life cycle and that the requirements of quality, reliability, and traceability are growing in the terms of object data. Characteristics that the information should have in a life cycle perspective is concretized by the authors as:

- The data needs to meet the requirements and create the information, and decision ground needed for stakeholders, at the right time.
- The information needs to be processed as well as extracted from earlier stages in the building's life cycle for efficient use of resources.
- The information needs to be permanently available throughout the life cycle.
- The information needs to be able to be updated, overwritten, expandable but with a historical timestamp in mind.
- The information needs to have a designated author which is responsible for the correctness and with a related liability.
- The information needs to be able to be processed (BIM-enabled) and/or machine-readable.
- The information needs to be accessed globally.

2.3.3.2 An operational information model

The owner of the real estate asset has the option to take control of the information produced and therefore potentially reduce the operational costs but also the costs of creating information, which traditionally has been created by the party responsible for the physical maintenance. There has been a rapid growth in applying innovative technologies, but the topics of applying technologies for operational stages of a building's life cycle are less discussed. If the FM's mission is to offer a service to people, businesses, and buildings, the quality of the information needs to be observed and to be seen as a crucial factor for the management of the building. Data reduction is therefore a paradox in the stage of information models. Data have a huge potential, but the information stream can not be functional for the operations since of redundancy. Building a digital model such as a Digital Twin therefore needs only to focus on including the most useful information, and not all available data (Bolshakov et al., 2020).

When a construction project is finished and handed over to the asset owner, so is all the information needed to keep the asset operational, mainly in safety, efficiency, and cost-effective measures. *As-built* information should be delivered to the owner in digital form, including detailed information regarding the maintenance and operations. How, and which information is handed over from the production phase, is specified and required in contracts in earlier stages of the project, all to minimize the cost related to additional work. As-built information is typically routinely done and should be a work-extensive addition to the project (Atkin & Brooks, 2015). As building information can include a large flow of information, it requires structured processes for collecting, analyzing, storing, updating, communicating, and controlling the information asset. As-built information is in this study categorized into two different types of information, Geometrical information, and non-geometrical information. Typical geometrical information that is considered to be important for the operational phase of a building are according to Atkin & Brooks (2015):

- Drawings from the different disciplines, such as architectural, structural, and other engineering drawings.
- Specification which includes the materials used and finishes.
- Inventory which is a classification system that show all plant, equipment, fixtures, architectural, structural, and building services.

Typical non-geometrical Information that is considered to be important are according to Atkin & Brooks, (2015):

- Materials incorporated in the building, name, type, cladding, species, and grade of timber.
- Materials that could be proven to be a hazard to health and safety.
- Plant, machinery, and equipment together with the supplier's manuals.
- Specifications of methods for special constructions.

As-is information or *as subsequently altered information* is information that is needed to be updated during the operational phase. Example of this information is defects detected, maintenance work, alteration, and renovation work (Atkin & Brooks, 2015).

2.3.3.3 The risk of tacit knowledge

The knowledge economy that forms today's market is requiring businesses to have good management of their resources, to be able to grow and remain competitive. Organizational intelligence formed by a strategic approach to alliances, intellectual capital, and the information and knowledge systems implemented, can also help an organization to build a sustainable competitive advantage. The theory of Strategic Knowledge Management (SKM) relates to the processes and framework that organizations use to create, share and obtain knowledge that lays the ground for strategic decision making (Ferreira et al., 2018).

It is essential within companies with large tangible and productive assets such as buildings to have knowledge about facilities. By transforming tacit knowledge which is embedded in operative resources, into explicit strategic knowledge is a key for successful FM. A lot of information, in many cases strategic knowledge is the head of persons working hands-on in the maintenance processes, forming tacit knowledge. In organizations where the knowledge transferring process is inadequate, valuable knowledge is lost when key employers leave. A phenomena often seen in organizations is massive use of informal knowledge transferring, meaning that information is gathered on islands within the organization (Cárcel-Carrasco & Cárcel-Carrasco, 2021). Further, Cárcel-Carrasco & Cárcel-Carrasco (2021) explains that tools for knowledge management can be beneficial to implement. In an example regarding maintenance of a production facility, tools such as information and knowledge maps, Agile and simple systems to capture experiences, and mobile computing tools that capture images, videos, and experiences, could increase knowledge transfer within an organization.

2.3.3.4 Creating knowledge and wisdom by data

The hierarchical theory of Data, Information, Knowledge, and Wisdom, also called the DIKW-pyramid is a commonly used theory within the field of information science, see Figure 2.7. It forms a hierarchy relationship between the terms, making a managerial model explain how data can be used. Being able to understand the fundamental concepts related to the hierarchy definitions of data, information, knowledge, and wisdom that needs to be clarified is a key for further research in the area (Al-Fedaghi & Al-Azmi, 2011). *Data* is a symbol set that is quantified and/or qualified, meaning that it consists of unrefined individual items, either numerical or observations. When data is put into a context and organized, it defines *information*. Information should answer the simple questions of What? , Who?, When?, and Where? *Knowledge* is consisting of a body of organized information, and added experiences, further defined as the understanding of what the information is saying and answers the question why?, How? and for which purpose? *Wisdom*, which is the end goal of the hierarchy is defined as the transformation of cognitive forms of knowledge into judgment and actions based on ethical decisions (Zins, 2013). Zins (2013) puts the theory of DIKW in a conceptualized context. In the process of creating a garment, data can be seen as cotton getting spun into yarn, which illustrates the information. The yarn creates a cloth, illustrating knowledge. And lastly, cutting and sewing the cloth, crafting useful clothing is considered wisdom. It can further be theorized as where each step of the transformation from cotton to cloth requires an input of work, and further an increase of organization, realizing the hierarchy of organizations. Value is created within the hierarchy, where data in itself does not create value until it is put into a context, organized and actions realized.

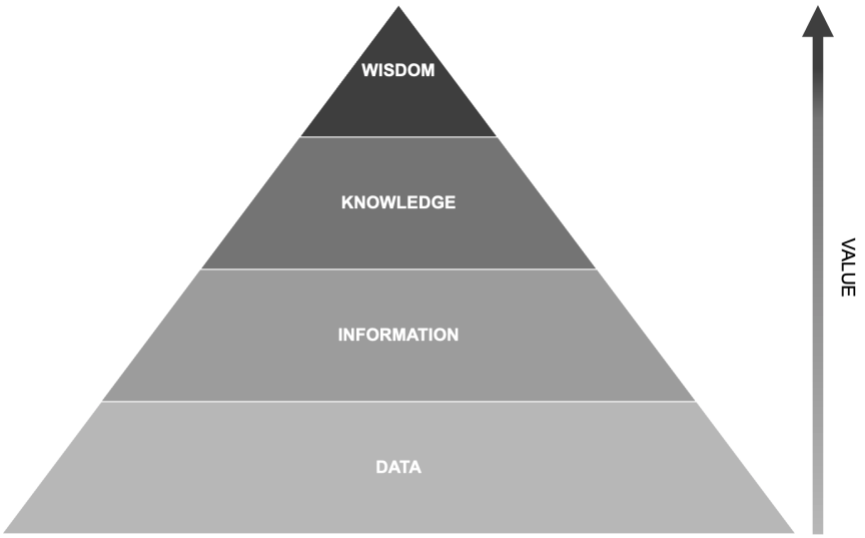


Figure 2.7: The Data, Information, Knowledge, and Wisdom hierarchiral pyramid (DIKW-pyramid).

2.3.4 Process

As the fourth aspect of digital asset management, processes include different standards, practices, and barriers. ISO 19650 is a new international standard for how to organize and digitizing information of BIM. After some words about roles and responsibilities within digital asset management processes, this standard is presented. Thereafter Scan-to-BIM and Building passports are described as another example of standardized processes for digital asset management. Finally, mapping of information processes is presented.

2.3.4.1 Roles and responsibilities

A problematic concern that is found within digital asset management processes and updating as-is-information is the uncertainty towards who is responsible for what activity. Atkin & Brooks (2015) explains that the best way to cope with this problem is to create a responsibility assignment matrix such as a responsibility assignment matrix (RAM-matrix), or a Responsible, accountable, consulted, and informed matrix (RACI-matrix), which should be anchored within the long-term information management strategy (Atkin & Brooks, 2015; Project Management Institute, 2017).
(Atkin & Brooks, 2015) explains that in case of alteration and changes to the physical assets, there needs to be processes and procedures for collecting, analyzing, storing, and updating the as-is-information and that it is stated within the assets owners information strategy.

2.3.4.2 ISO 19650 standard

Since there today is no standardization of what parameters a BIM model needs to include, it is up to each asset owner to determine the necessary information and therefore the data quality can differ (Ganter & Lützkendorf, 2019). There are however new international guidelines stated in the EN ISO 19650 standard, where processes of organizing and digitizing information of BIM. To reduce costs and risks of asset management of buildings. A schematic view of which processes the standard includes is seen in Figure 2.8.The standard requires early specifications on the information delivered on the finished project. Specifications are often done in the framework of a client and there the client plays a fundamental role and responsible for that the

requirements are met, it is stated in the Organizational Information Requirements (OIR). It further influences maintenance decisions where its requirements are stated in the Asset Information Requirements (AIR) as well as the project decisions which are stated in the Exchange Information Requirements (EIR). The methodology used in the ISO 19650 standard can be seen as the concept of starting with the end in mind (di Giuda et al., 2020).

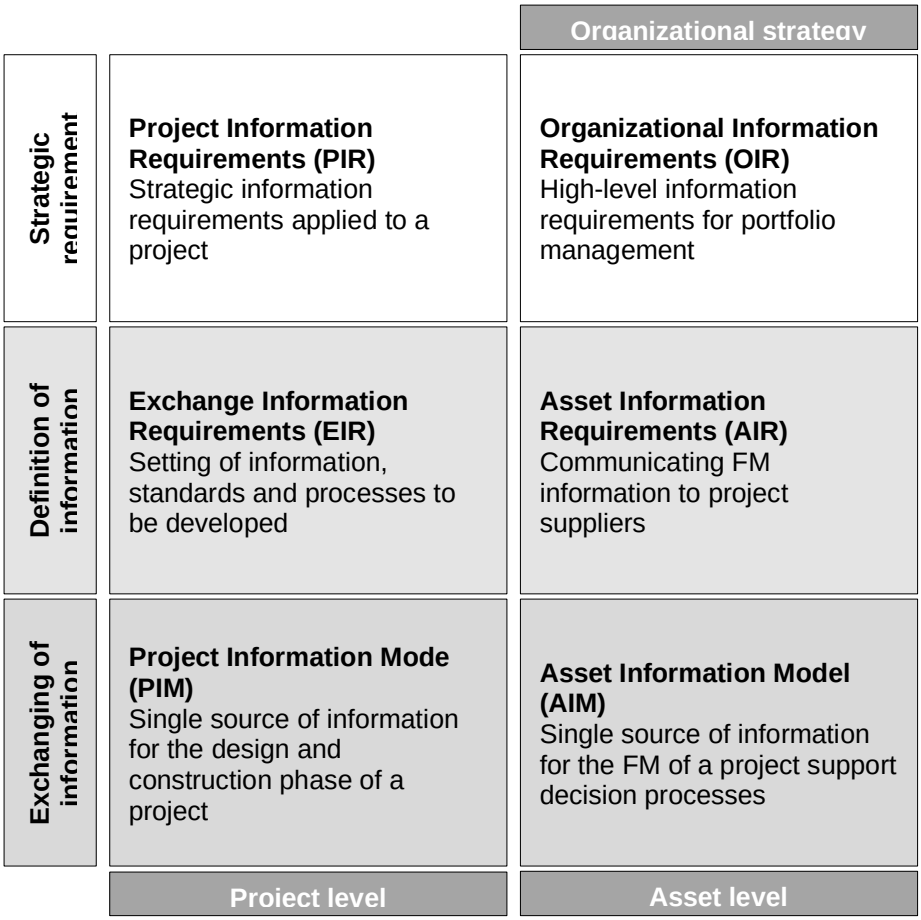


Figure 2.8: Information workflow ISO 19650-1.

2.3.4.3 Scan-to-BIM

Generating a BIM model with high accuracy in the latter stages in the building's life cycle is harder than in a newbuilt project, where the possibility to early specific and set requirements for the end product. The most commonly used process to create 3D models that represent the as-built in higher accuracy is Scan-to-BIM. This is a process that includes the use of 3D-scanning, also called LiDAR-scanning, which collects detailed data of an existing object such as a building, and generates a point cloud. The method of scan-to-BIM is still criticized since it has limitations related to time, cost, range, and recognition of objects which strengthens the view that creating and implementing this technology in existing building stock is a challenge (Carbonari et al., 2018). A Scan-to-BIM framework suggested by Wang et al. (2019) includes a four-step process which includes:

1. Identification of the information required:
    - Building elements.
    - Level of Detail (LOD).

- Non-geometrical information.

2. Determination of the required scan data quality:
    - Accuracy.
    - Spatial resolution.
    - Coverage.
    - Other properties.
3. Acquisition of scanned data
    - Scanning tool.
    - Scanning location.
    - Scanning resolution.
    - Other parameters.
4. As-is BIM Reconstruction
    - Modelling of the required building elements.
    - Modelling of required non-geometrical attributes.

2.3.4.4 Building passport

The concept of Building passport has been discussed in Europe for decades, where the objective is to provide information to a potential buyer, investors, renters, or user of a building. The term Building passport is further not yet defined, but it includes a certificate which are showing performance characteristics and technical data related to a specific building, similar to how documents are connected to a vehicle. It can further be a collection of various building-related documents such as building plans, calculations, declarations of materials, products used, operation and maintenance guidelines. Developing building passports may be strongly incitative for investors, financiers, insurers, and valuation experts, but also for a property owner to know the quality of their asset (Sesana & Salvalai, 2018). Ganter & Lützkendorf (2019) proposes on the topic of how data quality can be assured over a long period of time, that the concept of a building passport would set a minimum of information requirements that have to be documented and therefore show a solid data quality.

2.3.4.5 Process-oriented information mapping

Information is a vital factor in an organization, but it can be hard to guide how and by whom the information should be managed. To be able to take full advantage of the value that lays in information resources, identifying what information that the organization is creating and managing needs to be acknowledged. To build a working infrastructure for information exchange, the different steps, and activites that the organizations work with need to be defined. Further, defining which actor is doing what and which resources are used in the process makes it sharable and increases collaboration. This method of working is often referred to as *processes-oriented information mapping* (MSB, 2012). The focus of using processes mapping is to in an easy and pedagogical way, describe how the organization is working and where value is created. Processes are rather focused on what should be done and in which order, rather than on the tasks of a specific person. This makes an organization more dynamic and less dependent on individual knowledge. To start a mapping process, it is important to understand the current state of the organization and which processes or routines

3 METHODOLOGY

In this chapter the qualitative research approach is outlined, as well as the methods of case study and interviews. The collection of empirical data is presented, including the chosen method of a semi-structured interview study. Further, the methods for creating a methodological framework and the research ethics are explained.

3.1 Research approach

The study is conducted as a comparative case study with a qualitative approach. A qualitative approach is focused on the language (words, expressions, text) and its a richness of variation (Eriksson & Wiedersheim-Paul, 2014). Qualitative research describes a phenomenon in a context, interprets processes or meaning, uses theoretically based concepts, and seeks understanding. By signaling the qualitative nature of research, patterns can be described, explored, and explained. It's argued that qualitative research methodology increases innovation by its flexible approach. By not having a fixed framework of hard and objective features allows for softer and more subjective results. A qualitative approach can however be criticised for being subjective, in terms of the results being influenced by personal values (Hammond & Wellington, 2021; Silverman, 2015).

3.2 Building a methodological framework

In this section, the methodological framework underlying this study is outlined. First, the case study and interviews are presented. Secondly, the collection of data and how the study was conducted are described. Lastly, the study's research ethics, validity, and reliability are presented.

3.2.1 Case study

To gain a deeper understanding of how different companies in the real estate sector approach and organize digital asset management in the use and operational phase of a building's life cycle, and what barriers and enablers they are facing in relation to activity, technology, information, and processes, a case study of three different organizations have been applied. A case study is one of the most common approaches to qualitative research. But it is important to note that a case study is not a methodological choice on its own, it is rather a choice of what to study. Independently if the focus of the study is either holistically or analytically, the main focus is on a specific case of interest (Stake, 2000).

3.2.2 Interview study

Interviews have been used as a method to collect data. An interview study can simply be explained as a scenario where one person (the interviewer) asks predetermined or non-predetermined questions to another person (interviewee). In a situation where the interviewee has acquired the questions before the interview, the more certain and structured the interview will be, as the opposite for an unstructured interview. The structure of an interview can also be determined by how the questions are asked, if a question is asked as an open question, compared to one with a fixed answer, the interview is considered more unstructured. Open questions give the interviewee a chance to deliberate more on the questions asked and allow for more informal conversation (Eriksson & Wiedersheim-Paul, 2014).

3.2.3 Data collection

Three companies were chosen for the comparative case study. In the next chapter, these three companies will be further presented. The selection of the cases were made from the following criteria: the company should be a public actor, the property portfolio should have a majority of commercial and community space, the companies should be well-established. The sampling was also made by convenience. From each company, 2-3 informants were chosen for the interview study. The interviewed persons have been selected by the criteria that the person have a background within building asset management, and or digital building asset management. (See Table 1). The interviews were semi-structured. The same predetermined questions were asked to all interviewees, with a majority of open answer questions, together with fixed answered questions. The theme of the questions asked included the organizational view of digital asset management, the current and future technologies, the value in information, and how processes are used within the organization to enhance quality in the building's life cycle. This interview method is chosen due to the aim of gathering a holistic view of the information management process within the organization.

3.3 Research Ethics, validity and reliability

Stake (2000) argues that there is an informal contract between a researcher and the researched, explained as disclosing, but best not silent – a moral obligation. Therefore, considerations need to be taken into account in those cases where lives and expressions can result in unwanted exposure, loss of standing, employment, and self-esteem. This requires that the researcher is taking great caution of concern. The study was carried out in accordance with the general requirements for research ethics of the Swedish Research Council (2017) with regard to the information, consent, confidentiality, and use of data. The interviewees are kept anonymous to minimize the risk for unconcern and to increase the reliability of the answers given. As two of the interviews were recorded, the interviewees were given the opportunity to give their consent before it took place. Ethical considerations were also made to consider the degree to which the case companies could be kept anonymous. Since all companies were informed about the study and its purpose, a decision was made that possible identifications of the companies are still ethically justified.

Triangulation is a term used in research methodology, it involves the use of more than one method for the collection of empirical data and comparison between different types of information. It can also involve studying a question with different theoretical standpoints or a comparison between findings in different studies. In an example of an interview study, where different persons inside of an organization, with different roles, might describe events and activities in different ways. By applying a triangulation methodology, the validity and reliability of the research are increased (Eriksson & Wiedersheim-Paul, 2014; Hammond & Wellington, 2021).

Reliability is about consistency and replicability and is concerned with precision and accuracy. Validity can be discussed in terms of credibility accurate account of all steps in the research process and the opportunities to carry out a corresponding study in a similar way Bryman (2015). Throughout the study, there has always been a high ambition to present a methodical, complete, and transparent account of all phases of the research process. Both the choice of theoretical and methodological approaches can be

considered relevant for purpose of the study. Validity is also about methodological sustainability, and the research questions, the theoretical framework, and methodological approach are logically connected, together with the analysis and that reported the result, which can be seen as an expression of internal validity (Bryman, 2015). The result is presented openly, to be transparent to external criticism.

4 Case companies

The empirical data collection is gathered by a case study consisting of three different case companies, Jernhusen, Västfastigheter, and Akademiska Hus. This chapter introduces the different companies, characteristics of the property portfolio, organization, as well as a short introduction to the interviews, summarized in Table 1.

Table 1: Overview of conducted Interviews.

Case companies	Interwiewees		
Jernhusen (A)	Technical Manager A	BIM Strategist A	CIO A
Västfastigheter (B)	Technical Manager B	Digital Innovation Strategist B	Digital Assets Strategist B
Akademiska Hus (C)	Business Developer C	Information Manager C	

4.1 Jernhusen (A)

Jernhusen is a public real estate company with a focus on managing commercial properties related to the Swedish train network. The company aims to increase the public transportation as well as increase the amount of freighting on the Swedish railroad system. By having a different kinds of business areas, categorized by the properties included, where the business area, also referred to as the different area types, *stations,* and *maintenance depots & combi terminals,* Jernhusen's property portfolio is characterized by diversity as well as complexity (Jernhusen, 2020).

4.1.1 Property portfolio

As per the financial statement of 2020, the distribution between the different property types are consisting of a total of 90 properties in the station's area, with a rentable space of 191 000 sqm, and with 56 properties related to maintenance depots/ combi terminals, and with a rentable space of 391 000 sqm. Further, the business area stations include offices, commerce, restaurants/cafés, hotels, station operations, and more. The business area of depots & combi terminals includes to a large degree industry and depots, warehouse and logistics, and further a smaller part of space utilized as offices, hotels and other. The properties are distributed with a high geographical differentiation in connection with the Swedish railroad system, from Katterjåkk train station, located in the far north of Sweden, to Malmö being located approximately 1450 km to the far south. This implies large distances between some of the properties being managed (Jernhusen, 2020).

4.1.2 Roles, working areas, and interviewees

4.1.2.1 Technical Manager A

Technical Manager A (TM A) has been working for the case company for four years and has previous experience in both the role as a technical manager and as a operations technicians. Based on a large previous experience accompanied with an educational diploma in real estate management, the interviewee is assumed to have a senior role within the company. The interviewee is based in the region of Stockholm and manages

different property types, with the main focus on industry and depots, located in the north of Sweden.

4.1.2.2 BIM Strategist A

The BIM Strategist A (BIM A) has been working within the company for two years and has previous experiences from working with digital transformation at a consultancy firm. BIM A's experience accompanied by a Higher Vocational Education is considered to have a senior role within the Jernhusennd works with strategical decisions at the companies technical department.

4.1.2.3 Chief Information Officer A

The Chief Information Officer A (CIO A) has been working with the company for two and a half years and is traditionally consulting in the role of a Chief information officer (CIO) as well as a Chief Digital Officer (CDO). CIO A has previous experience as a digital change leader and worked with change processes within multiple organizations and sectors. CIO A has a leading role in the digital transformation of the company.

4.2 Västfastigheter (B)

Västfastigheter is a public real estate company that manages the region's community properties, with an aim to provide sustainable environments for the region's different functions. The region is responsible for health care, culture, public transport, and regional development in the area. The company employs approximately 400 people.

4.2.1 Property portfolio

Västfastigheter's property portfolio consists of an approximated 1,7 million sqm of rentable space, divided between health care facilities, museums, educational facilities, tram depots, and a botanical garden. It makes the company one of Sweden's largest property owners, with an annual rental income of approximately 2,2 billion SEK and an investment outcome of 3,8 billion SEK as of 2019.

4.2.2 Roles, working areas, and interviewees

4.2.2.1 Technical Manager B

The Technical Manager B (TM B) has been working for Västfastigheter since 3 years back and was previously working for a consultancy firm for 10 years. TM B has a university education as a landscape engineer. TM B manages the land and outdoor environment of 22 properties in the region.

4.2.2.2 Digital Innovation Strategist B

DI Strategist B has been working within Västfastigheter since 3 years back, before the role as a digital innovation strategist, Strategist B worked as a BIM-strategist within the same company. Strategist B has an educational background as an architect and previously worked with strategic questions regarding digital asset management, similar to the current role.

4.2.2.3 Digital Assets Strategist B

DA strategist B has been working for the company for eighteen years and also worked in a strategic position in the company for many years. Previous roles within the company included the role as a CAD manager and strategist, and later the head of the unit for digital assets.

4.3 Akademiska Hus (C)

Akademiska Hus is a publicly owned real estate company which has its focus on construction, development, and managing environments for education, research, and innovation. The company aims to strengthen the universities' attractiveness and sustainable development as well as to offer services which enhances the campus experience of the 300 000 persons who daily are utilizing the buildings.

4.3.1 Property Portfolio

The property portfolio consists as of 2021 of a managed area of approximated 3.3 million sqm leased area, to a value of 100 billion SEK and have a turnover of 6.5 billion SEK. The leased space consists to 45 percent of teaching facilities, 35 percent of laboratories, and 20 percent of uncategorized facilities. The portfolio has a large geographical diversity with facilities from Luleå in the northern part of Sweden to Malmö in the south.

4.3.2 Roles, working areas, and interviewees

4.3.2.1 Business Developer C

The Business Developer C (BD C) has been working for the case company for a total of sixteen years, in different roles such as a project manager and as a business architect. Business developer C has previous experience in economics and management consultancy.

4.3.2.2 Information Manager C

The information Manager C (IM C) has been working for the case company for two years and has earlier experience from consultancy. IM C works in the department team of technical information management, which is responsible for the information systems, quality assurance of as-built documents, the responsibility of the main archive, and public archive.

5 FINDINGS

In this chapter, the findings from the interviews are presented, each case in turn. The result from each case is structured according to the research questions. At first, the respondent's narratives about how their companies approach and organize digital asset management in the use and operational phase of a building's life cycle are presented. Thereafter, the interviewees answer about what enablers and barriers their companies are facing in the strive of having high quality and reliability of their digital assets during the use and operational phase of a building's life cycle. This part of the result presentation is divided into four themes; activity, technology, information, and processes. Even if these four aspects are used as analytical categories, it is important to keep in mind that these not always can be completely distinguished from each other. More often they are overlapping each other.

5.1 Jernhusen (A)

5.1.1 Organizational view of digital asset management

BIM A explains that to understand the organizations' ambitions in regard to digital asset management, it is important to understand the company, which is a state-owned company but with a commercial responsibility. The company has profit demands, meaning that the company must generate value for the owners which is the Swedish government. In order for the organization to have a more efficient business, it needs to become better at everything they are doing, this includes everything from better facility management, to developing, renting out, and taking care of the tenants. In order to do these things more efficiently, there is a common denominator which is to have knowledge of the properties, what is being rented out, what is being designed, and what is going to be managed. Further, in order for this to happen, a change is required in how the company works today, a digital change process, with the aim to have accessible and up-to-date information to enhance knowledge of the portfolio. It is a big change process that the company is in the middle of. BIM A believes that the first step in this change process is to start in the right direction and to clean up the information, and find processes for how it should be kept up-to-date in the future.

Both BIM A and CIO A describe how the company does not view itself as a driving factor of the digital change of the sector. The aim is to be the best implementors of new technology, rather than forcing a digital innovation and being early adopters. This implies that the organization sees itself in a strategic position of implementing the proven and existing technologies that are on the market. The strategy chosen is due to the fact that the company is a smaller actor, there is a low level of digital maturity, and cultural barriers are influenced by decentralisation and a diverse understanding of the ongoing change process.

Recently, according to all informants in Jernhusen, a large investment has been done in the terms of digital asset management, where resources have been realized in a large digital inventory project. The project resulted in that a big portion of the property portfolio got captured by 3D-scanning, with the aim to provide the organization with accurate BIM models, point-cloud, and a new solution for a digital twin viewer. During the same timeframe a new facility management system was implemented, with a large number of new functionalities. These investments implicate that the organization have made a large leap in terms of technological evolvement, together with a gathering of a

large amount of facility information, as well as setting the quality of the digital assets of the property portfolio. The results from the digital inventory project might give implications since processes for how the new digital assets and systems are going to be managed and maintained are not yet defined to a great extent. The organization is also embossed with a large diversity in the digital maturity, where a large portion of the employees is of higher age and is used to a more traditional and analog way of working with property management.

Jernhusen has chosen to outsource most of the activities related to both physical and digital asset management to focus on the companies core activities. Further, Jernhusen is aiming towards a new business model which implies that instead of selling a physical good, the customers will receive a service. As an example, CIO A explains that the traditional lease contract of commercial properties includes rent which is mainly dependent on the square meter of the space. With the new service mindset, the rent of the space would rather be decided by the amount of exposure and pedestrian that is passing the space. CIO A explains that this business model is heavily dependent on technology such as digital twins and IoT, and of course a fully implemented digital asset management processes.

5.1.2 Activity

The technical manager A (TM A) has the responsibility to manage propertys technical installations, as well as the overall construction of a building. In the role as a technical manager, TM A's responsibility includes maintenance planning, space management, energy management, emergency management, and monitoring of several maintenance depots, short-term accommodations, and offices which is spread across the northern part of Sweden, with large distances in between. TM A interprets that the managed property portfolio is characterized by a large complexity, mainly due to the fact that there are large governmental requirements on safety and emergency management, for example the train depots are in direct relation to the railway yard which both has trains in motion and a lot of high-voltage lines, requiring systematic fire protection work and repeated inspections by authorities. The high complexity is also influenced by the age of the buildings, a lot of the industrial buildings managed by TM A have an age above a hundred years, which means that a lot of care needs to be taken in terms of the building standard and implications of older installations. TM A mainly works as a client, in the terms that a lot of the daily operations, maintenance work, construction, and renovation projects are outsourced to external parties.

In the role as BIM strategist, BIM A is responsible for design instructions regarding BIM, and how to ensure the quality of design, and what is expected to be delivered in a final delivery from construction projects. The role includes developing BIM strategies and overall strategies for how the organization is working with technical building information. Also, strategies for keeping the information updated, and reliable, is a crucial part of working with information-driven management. BIM A is also running innovation projects where recently a large drawing project was done together with a consultancy firm. Other projects include evaluation of the requirement for building information as well as developing the requirements set. All to answer the question of how the organization can become better decision-makers and clients.

BIM A have been part of the implementation of a new IWMS system where BIM A contributes with the knowledge from drawing documents, models and building

technical information. All to answer the questions of which information should be in the system, and how it should be used and updated. To summarize, the role includes how should the organization use building technical information, and what information should be used, and how can we get it from projects.

As a CIO/CDO, the responsibility is to lead the company through the digital transformation process. CIO A is however only in charge of the actual change engine and states that even if the responsibility includes initiating a project such as the digital inventory project, where the objective is to deliver digital building assets in the form of models to the management operation. CIO A explains that it is now the responsibility of the management organization to make sure that the assets are being managed correctly and according to the specified operation and maintenance processes.

5.1.3 Technology

The TM A uses a lot of different technologies regularly, such as an energy system for energy management, A IWMS-system where AFF-codes (Agreements for facility management) are updated for each property and are linked to an error report system.

Recently, Jernhusen has acquired a platform for the use of a digital twin which is based upon point clouds and photogrammetry, together with the opportunity to integrate other data formats. Object information is spatially attached to objects within the 3D space to make it possible to store non-geometrical information. This new technology is well received by the TM A who are using the digital twin in their daily activities. For example, has the digital twin allowed TM A to monitor the property portfolio in a cloud-based environment which is saving both time and resources. The Digital twin has also allowed the TM A to offer viewings of a leasing customer, allowing space management, measuring, and applying for building permits, without having to visit the property physically.

BIM A governs the technological innovation process as well as how its to be used. As being in a strategic role rather than operational, BIM A focuses on how the different technologies should be implemented and used for the organization to gain the most benefits of the technological evolution.

The digital change process that CIO A is leading has initiated the technological evolvement towards BIM through the digital inventory project and is a strong believer in that a digital twin solution with real time data is the future for the company. In the near-future CIO A believes that point-cloud-scanning will be cheaper and easier, more accessible and sees a future solution where realtime capturing can be done through a smartphone or tablet.

5.1.4 Information

TM A explains that the main information needed for managing the buildings are as-built documents in the form of disciplinary drawings, including architectural, technical, electrical, HVAC and plumbing. Since TM A in the role as a client uses external parties for a lot of the maintenance and inspection work, information about some of the technical installations, such as elevators, industry gates, pressure vessels, and more, is supplied by other stakeholders. TM A considers that the information that is needed to manage the activities are sufficient. To which extent the information is updated and reliable, TM A explains that mainly the as-built architectural drawings are up to date,

but that the technical drawings of plumbing and HVAC often is very unreliable and outdated. A lot of the information is very old and requires that operational personnel often recalibrates and inspects the current drawings before any maintenance work gets done. To concretizes, TM A interprets that information 10 years or older, often is not reliable and can't be trusted. A reason why the older information cannot be trusted is due to that there is a lot of actors doing changes in the building, often unauthorized and therefore creates and unreliability when the changes are not added to the information sources. Further, TM A explains that at the end of the day, the role of a TM includes having the responsibility to assure that the needed information is available and up to date.

TM A means that the information with the highest necessary quality and reliability mainly is the information that is related to safety concerns. This includes electrical drawings and information, fire safety drawings, and information including which walls are closing a fire cell and further the architectural plans since they are governing information. TM A means that the information should aim to follow the building standards in the form av quality as the governing building norm, meaning that the current building norm should implicate highly detailed and precise measurements e.t.c.

TM A further explains that an aim is that if someone is gathering information regarding the property's condition, high or low, it should be communicated and brought up within the organization, mainly at meetings. TM A means that this is of high importance since the distance between TM A's place of work and the properties often is far. The information that is brought to TM A is often considered too small to include in the as-built-documents.

BIM A explains that there might be as little as 10% of the designed information or as-built information that you actually use in a management phase. After talking with the internal management operations, BIM A means that it is hard to define which information is needed to manage a building. This mainly due to the fact that there is big question in regards to what is the need-to-have rather than good-to-have information. The answer to what information is the absolute minimum for managing a building might be as little as an address to the building, a well-executed maintenance plan, and the exact square meters. Contrary to information such as how many square meters of suspended ceiling is in the building, might be good-to-have information, but not a need-to-have. BIM A also means that the organization traditionally has had a large focus on the nice-to-have information which is about to change.

BIM A further specifies that the largest priority of information, as of now for the organization is architectural plans with the right square meter since it is governing towards the leasing contracts, and allows for design work and simple management. Further, regulatory requirements are of great importance for the organization as well as components that are especially interesting for the operations, such as lifting jacks and overhead cranes. What is not as interesting to manage is information such as fire cell boundaries or other invariable information since it is not used for management today. BIM A means that is of what is of interest today, in the future other regulatory might be need-to-have information, for example if the governmental needs of environmental data are increased.

As the author of the BIM specifications of the delivery specifications, it is BIM A's responsibility to anchor it to the technical managers' need. Information such as classification of building components, BIP or BSAB-codes, or a logical name and building component is the form of the basic structure for the model to be called BIM. This means that the wall needs to know that it is a building component of a wall, but what is also specified are the component information on certain selected objects, the operation and maintenance projects that require regulatory supervision, where there are rules and laws regarding monitoring of certain information. This can for example be the type of refrigerant and its quantity, this is further added to the delivery specification. From projects, the delivery responsibility has been divided into where the designers have a responsibility to deliver a structured model with detailed information on building parts, and where the contractor has a responsibility to deliver operation and maintenance information on the selected component that has been specified. If this information is delivered to a database, model, or in a spreadsheet does not matter. Overall the amount of information that is demanded is based entirely on the needs of the administration, BIP, BSAB is to be able to design nicely and to enable quantity take off, crash checks, and communication.

Information is going to play a vital role in the future for the companies business model. In a couple of years, the aim is to besides delivering a physical space, a service of information will be provided to the customers. This requires that the information ground is going to successively be built as time passes and that technology and processes are playing their role.

5.1.5 Processes

From a TM's perspective, the organization is influenced by decentralization where the role as a TM has a responsibility to keep the information about a property up to date. TM A means that there are different instances within the organization which work as supporting functions to the management of building information, however from project deliveries and maintenance work it is up to the TM to supply and demand the right information in return for the executed work.

The people working with maintenance in the facilities have supervision and maintenance orders where the orders are specified in detail, the personnel also have round orders which include reporting suggestions for improvement, and if there is a faulty installation, it gets reported into the system and providing statistics.

As technology often is not the main barrier for digital change processes, BIM A is keener to focus on the organizational barriers that are present in the company. The main take is that the organization has not yet defined a process that is allowing the quality of the information to be held during a building's life cycle. The company now has had large deliveries of BIM models through the digital inventory project, and where the models now are mainly geographical information and architectural models. The idea today is that whenever there is maintenance projects that are doing changes within the buildings, the model is complemented with these new changes. For example, if a renovation of an HVAC-system is being carried out, the project delivery is specified and the model is refined. The level of details of the digital assets should therefore continuously be improved, as long as there are renovation projects being carried out. However, as BIM A mentions there is a large span between the utilization of different properties within the portfolio, for example, a commercial railroad station in the city

center of Stockholm, where a higher utilization creates higher demand and more maintenance projects, and where tenant changes are happening very frequently, will have a complete BIM model with high quality in a short amount of time. In comparison to for example a station located in a lower density city such as Alingsås, the utilization is lower, and not many maintenance projects are carried out, resulting in a far longer period for achieving a complete BIM model.

BIM A means that since a lot of the responsibility of how the digital assets management is carried outlays in the role of the technical managers, which are the information owners, the digital asset management processes will differ a lot. Technical managers with high digital maturity and who are utilizing the new digital technologies such as the digital twin, and who understand the importance of implementing processes for the management of digital assets, will also see that the change process will be faster and more beneficial.

BIM A further explains that the organization needs a role that is working operative with the digital asset management to keep the information maintained. The technical managers often do not have the skills and knowledge to hands-on maintain a 3D model, and the digital twin that has been implemented does not allow for its users to write and add geographical information by themselves. For example, if non-planned changes are happening within a property, such as a service gate malfunctions, the quality, and reliability of the model is lost, as long as the models are not updated or that it is reported to an information manager who is updating the information-sources.

In the new IWMS-system that has been implemented, there is a reporting system for unsuspected changes, as well as characteristic changes in the result of maintenance work. Where operational personnel can notice damages and changes by taking pictures and specifying by notes. However BIM A means that there are yet no routines and processes being communicated to use this tool regularly, also, cultural barriers make it hard to implement such processes. BIM A also explains that it is important that all stakeholders who are utilizing the building have the ability to do this kind of reports, to maintain a high quality of information throughout the building's lifecycle.

The digital twin solution that was introduced in the digital inventory project, BIM A explains today works as a viewer of geometrical information including point-cloud-data. The digital twin is not viewed as a main carrier of information and is further defined as a complementary tool for the technical managers who need the ability to in an easy way monitor their buildings remotely. For the digital twin to be maintained BIM A, means that there need to be incitements for the use of the solution and a need for maintenance of the information.

CIO A explains that it is the technical department of the company that is responsible to create the framework for the future digital asset management processes, including setting up the right systems and guidelines for what is going to be managed. After the processes are created it is up to the property and technical managers to make sure that the processes are being followed. CIO A further believes that a lot of the digital asset management is further going to be kept outsourced since it is in the companies interest to have a slim and core-business-focused organization. A future scenario might however be that the operational personnel will be doing inventory checkups with a smartphone or tablet, creating an information ground that will be communicated to the

IWMS-system and asset-data base, which further will allow generating spatial coordinates both in a BIM model and in a point-cloud-environment. The company has already started to equip the personnel with hand-held devices and have as a strategy to do inventory rounds to successively build up the information value.

5.2 Västfastigheter (B)

5.2.1 Organizational view on digital asset management

At Västfastigheter the interviewees explain that the organization has realized that it needs to create a larger information base and utilize the new technologies that are on the market. When the organization has been presented with new digital systems and technologies, there has been a self-understanding that there are large barriers related to the digital transformation. The organization is currently struggling to implement processes to the extent that as-built documents in 2D-CAD and PDF files are being delivered and maintained correctly. The result is that there are major risks in taking a digital leap towards a higher information ground if the bone structures are not there yet. The strategy has therefore been to build the processes and knowledge before accelerating the digital evolvement.

TM B explains that in the past 4-5 years there have been made large organizational changes, whereof the management have seen a need for a more strategic management organization that is capable of setting the right requirements, both regarding the technical properties but also the digital assets. The transformation has resulted in that the technical managers during the time have increased from being approximately 25 persons to 90 persons, and increased investment within the area of digital asset management have been done. The team has strengthened its competencies in the areas of BIM management and digital development, and today the team consists of information managers with geographical distribution, BIM-strategists, Digital innovation strategist. A larger understanding of the value that lays in information has also been established within the organization.

The organization is strongly influenced by political governing and have slowly started to realize that the organizational barriers need to be solved for the organization to work strategically and proactively as an information-driven property owner. The digital maturity within the company is varying, as a result of having a large age span and lacking directives and initiatives from governing actors.

The company is in the process of finding a common future in the area of digital asset management, and figuring out what the goal is for tomorrow, for 1 year, 5 years, and 10 years. The DA strategist B explains that there must be an idea to create conditions for what the company aims for towards the future, there need to be short steps taken but in the right direction. Some things might be the same in the future, whilst there will be an increased focus on information, system support, but overall it should be based on our needs and wishes. The company sees a future in Digital Twins and the use of these new technologies, however, it needs a basic structure upon which the new technologies can be built upon.

5.2.2 Activity

DI strategist explains that the company has a history of not having clarity in the roles, responsibilities, and guidelines within terms of digital asset management and that the overall digital asset management processes were decentralized. This is however in the stage of definition.

In the role as technical manager for the land and outdoor environment, it includes working with long-term maintenance planning, being an expert on the subject of outdoor environment, create, implement and maintain technical requirements and guidelines, ensure that the regulatory requirements are being followed, being responsible for long-term and strategic planning, maintenance and investment planning, participation of risk and vulnerability analyses, collaboration with management, operation and service and participate in the development of systems and functions. In the role as TM B, the main activity is acting as a client, including conducting feasibility studies, requires deliverables, and ensures that the projects are carried out properly.

As a digital innovation strategist (DI strategist B) the responsibility is to know about what is happening within the sector, developing strategies towards the digital asset management processes, be up to date regarding laws and regulations.

Digital Assets Strategist (DA strategist B) the main role is to develop processes for digital asset management, including creating a team and to stimulate good teamwork. The role also includes meeting the other stakeholders who is in need of digital building assets.

5.2.3 Technology

Today TM B mainly works with a newly implemented IWMS-system where a lot of the information is being stored, this results in a transition from the current use of spreadsheets, PDF documents, and notes. TM B utilizes the AFF-code system which is further used for maintenance planning. Since the organization has recently implemented a new IWMS-system, a large change process is in progress where TM B is striving towards getting a tool for carrying out the management efficiently. The current technologies that are being used are as TM B explains not allowing for a holistic view of the outdoor environment. TM B means that the way geographical information is being handled in the 2D models/ drawings in combination with the use of static non-geometrical information sources creates a barrier to the activities being executed. TM B explains that there are currently pilot projects and development of processes for new technologies to be used, whereof geographical information systems and spatial data might be utilized. TM B further sees that there is a potential value in 3D models and digital twins.

The main focus of the organization today is to implement a structure for BIM management, there is however an ambition to in the future be able to utilize the technologies of point clouds and digital twins, but DI strategist B does not believe that the organization is ready for such a digital leap. One of the reasons is that there are no tools that are plug- and play and adjusted for the current way of working, and there are monetary barriers towards implementing new systems for digital asset management. Also, the tools and knowledge to maintain digital twins do not yet exist within the organization. DI strategist B also explains that there is comfort in using the traditional 2D-CAD-drawings since it is a very manageable and user-friendly way of working with

geometrical information. The organization is further adjusting to keep up with the evolvement and to utilize the benefits of BIM. One project has been initiated where an external party has delivered a BIM model through scan-to-bim methodology, but it is still in a pilot phase.

DA strategist B believes that processes and organizational structures are prior to the technological evolvement and that the reason for the company to rather develop a base structure than focus on implementing new technologies. The main technological focus is at the moment to create the organization for BIM-management, a new IWMS-system is enabling this technological factor.

5.2.4 Information

For TM B to be able to complete the activities that the role includes, requires TM B to have knowledge of the different types of installations and their spatial orientation. TM B further explains that the information need is varying depending on which system support is available and to which level of detail the planning is needed for the situation. This means that in a case where there is long-term maintenance planning done, the most important information to have is the installation type, which is connected to an AFF-code, a quantity, or boundary area. This means that it is necessary to for example know that there is this quantity of benches, this amount of asphalt, or this number of trees. In the terms of short-term planning, where the maintenance is supposed to result in a maintenance project, the information that is needed, must be of higher detail and with technical specifications. This indicates that the type of benches, load capacity of the asphalt or age and, family of the threes is important.

TM B explains that the information that is needed for the activities to be executed is possible to generate, however it requires a lot of administration and it is not easily accessible. The information that is available is also often not reliable since the organization has not been working actively with specifying requirements for deliveries. This, however, has been reciprocated and TM B has now started to set stricter requirements in terms of governing documents. The reliability of the information is low since TM B explains that the information always needs to be double-checked, either with someone that have tacit knowledge of the property or to do physical surveying. TM B however means that this is something that will continue shortly since it is too costly to keep all the detailed information up to date. As an example, the elevation plan is something that always needs to be recreated for each project, even though a general elevation plan can be of use for the management.

The amount of time spent on searching for the right information can vary a lot, TM B explains that a bad week, or when large maintenance projects are being done, a lot of time is spent looking for information, whilst other weeks does not include a hard search effort for information. TM B explains that the amount of time has been reduced over time that tacit knowledge has been gathered about each property. Further TM B does not see that there is a lot of costs connected to searching for information since it is a part of the job to go out and view the managed properties.

DI strategist B explains that there is a lack of information for decisions being made which is resulting in reactive management. Information is being uncategorized and is often spread across different systems or is stored in someone's head. Information is often being unutilized when operational staff is storing information on local databases.

On top of the flow of information is the lack of an overview schematic scheme of how information should be transferred. Technologies and systems are being used without interpretation between other systems and on top of all this there are the organizational barriers of high staff turnover and low digital maturity. DI Strategist B means that different pyramids of information are creating a bubble that is about to burst and creates a need for a new way of working with digital assets. DI strategist B describes that previously the organization has had problems finding a common path towards how information should be managed, the systems that had been implemented did not have interoperability, meaning that the system could not communicate with each other, there was a lacking system overview, and no process mapping existed.

The information needs to be open and applicable to fill the information need we see, there will be a space for IoT and automatic simulation, AI self-planning, and using the information to get things as good as possible and with a focus on effectivise the use of resources.

There is a discipline that owns the information related to that discipline, technical managers have the responsibility to decide what information is needed for the activities to be executed. The information manager is the administrator of the information but do not have the responsibility for the fact that the information is true, however, the information manager is responsible for what technicalities are needed for it to be administrated. In the terms of CAD/BIM models, the information manager is a supportive role within the projects, answering questions such as which attributes should be included and which preferences are needed for the metadata to work. Previously the different roles were decentralized, meaning that each part of the region worked as its own unit in terms of both information management and technical management, this still has an influence on how digital assets look today.

The main take is that the information always needs to be born in the management needs, this requires that the information is specified together with the technical managers, information owners, and information managers to set a required need-to-have information level.

DA strategist B strongly believes that to information to achieve a high quality over a building's life cycle, a single-point-of-truth needs to be in place. If the same information has different sources it will result in miscommunication. Single-point-of-truth is one part of the structure that the company is building, all actors need to be on the same page of where information is stored, connected, and information and system mapping is needed.

5.2.5 Process

TM B believes that processes and routines are the pillar of a working digital asset management model, where rather than pointing towards new technology, the organization needs well-defined ways of working that are also anchored within all of the involved stakeholders. Technology is available, but people need to keep up with it.

The roles within the maintenance process of digital assets are today not defined to a great extent, the technical managers together with the property manager is to one extent responsible for the digital assets, but there is a lot of technical managers that do not have the compentence to administrate the geometrical in CAD- or BIM-softwares. In

this case the function of information managers is playing its role as an operational administrators. There is however current work within the organization to sort out these processes and to become better at requiring the right information.

Since the organisation cannot manage and maintain a high amount of information, it is crucial that the managed information is stripped and only consists of the absolute need to have information. This means that when there is a delivery from projects, a well-refined and operational information model is delivered. The changes that are happening to a property are in the framework of a bigger project, such as new construction, bigger areas of change. Smaller work is not necessarily resulting in updated digital assets. There are functions within the new IWMS-system to do note smaller changes on a daily basis, including a way to draw symbols on the drawings, this function however requires TM B to actively administrate the changes and it is as of now too demanding.

Overall TM B believes that the organization has done a great job by developing new standards and delivery specifications, and believes that as of now it is time for implementation and continuously try to refine the current digital assets. The change process requires that all stakeholders follow the new standards, that there are routines for validation, and that whenever maintenance projects are happening, the operational information models is actively updated and maintained.

TM B sees the potential of the new trends towards BIM- and Digital Twins but expresses that this also requires that there are processes for maintenenace and that there are easy ways for operative personnel to make changes to the models.

DI strategist B explains that the current digital asset management processes are continuously getting interrupted by human factors, for example, each time a project manager requests as-is-drawings, the quality is low and a new survey and as-is-designs needs to be developed before the project design even has started. The same occurs when external parties recieve information, resulting in that information needs to be double-checked and validated. DI Strategist B explains that this is the result of human factors and that the current processes and guidelines are not working properly.

DA strategist B explains that to understand the digital asset management process the different projects needs to be explained, there are different project types of different size defined as:

- Investment projects which usually are larger projects where a budget is set and that affect several disciplines.
- Planned maintenance projects which are initiated by the operational and technical management, often with a focus on installations such as tear fence, a ventilation unit.
- Customer projects, where our property managers together with customers are governing projects such as room adaptions, moving walls, knocking out smaller rooms, etc, and are ofter smaller projects.
- Property committee's projects which are technically driven by investment, more focus on development.

Depending on which project type is being executed there are different incentives in the role of digital asset management. The investment project will often finance a complete redrawing of either as-built-document or in a BIM model, however there has

traditionally been problems with the as-built documents being deliveried on time and of lacking quality, this is a focus area since it's rather an easy improvement to get actors to follow the processes and the set deliverable requirements.

Planned maintenance and customer projects are often too small for being update since the cost for updating the geometrical information can not be justified. DA strategist B also means that there is low interest from external parties to do these updates since it is such a small job. DA Strategist B explains that processes need to be developed, there is currently an errand function in the new IWMS-system but it does not fulfilling the right criteria. In one of the geographical areas changes due to the smaller project gets noted through manually scanning of a report paper and is deliveried in a PDF-file to the information owner.

In the thesis of a digital twin DA strategy B means that all changes of the physical property also need to change the digital assets, because if the process for updating information is lacking, the information becomes unreliable and not trustworthy. And back to the actual need to have information, we need to categorize to which extent information needs to be maintained before we invest in new technological systems. As of now we know that the architectural model is of great importance for the geometrical boundaries, and it needs to be updated continuously since there are FM-services that needs to know what to clean, which area is being rented out, and which contract is in place, for orientation in the buildings, then we can't just update the architectural model once a year. On the conterary, other information types is not of great importance, where just a note which is saying that there has been a change is enough, that it is in a list of changes that need to be updated. A function for redlining, digital post-its could be a compliment for this case. This requires that there is a value chain of objects which is interpreted within other systems and once a year the list gets checked and the information is updated by an external part. Overall, we manage about 1.7 million square meters of space, which on top of that have 15 different types of geometrical drawings, it creates a question if it is even possible to keep all the information alive.

DA Strategist B explains that there is a strive to have a digital errands system which are seamless and accessible to note changes which is occurring to a property. Also, everyone working in the property must be able to note changes, so if for example, someone from the cleaning staff notices a change it can be easily noted in, for example, a mobile application. Depending on who is doing the change there might be a classification of however the note should be investigated further. What is also important in the case is that each errand gets feedback and gives incitements for future errand-making. A rating system could be implemented but it needs to account for the different types of information level, sometimes there is the information required to an as-built standard whilst others have a lower detail level. It also requires a classification of which information is the most necessary and that projects get a good follow-up. A future case could also be digital inventory checkups, systematic checks the digital assets. DA strategist thinks that measurability is important for feedback reporting.

5.3 Akademiska Hus (C)

5.3.1 Organizational view of digital asset management

BD C and IM C both explains that the company has a long-term strategy and goal to create a common information model within the whole company, today the company have started to work more organized with the topic of digital asset management, where object modeling and information volumes are creating a data warehouse, mapping of buildings have been initiated, digitalized agreements are in place, master data systems and getting control of information flows and working in information layering. The main argument is that there has been a common aim towards working systematically with digitalization as a crucial business benefit, both practical and operational. By getting control over the information it has allowed the company to easier adapt and change to new systems, for example when implementing a digital twin solution, the company was able to connect existing room data for external communication.

The position that Akademiska Hus has taken involves being a driving force in the digital transformation of the sector. The company sees itself as innovator mainly due to the progress where two digital twin projects have been conducted with a proven positive result. BD C explains that because it is a public company it needs to motivate the work being made, not only in monetary terms but also its sustainability and the value provided to customers, being the higher educational institutions. A big part of the digital evolvement that the company is facing is driven by the needs of the customers as well as the internal operational management.

IM C and BD C both explain that the organization has strenghtened its competencies towards digital asset management with dedicated technical information managers, solely responsible for the digital assets.

IM C thinks that there is a diversity in the digital maturity of the company, some persons have a large driving force in the digital transformation, whilst other do not see the benefits of it. However, IM C believes that digital maturity is rather high in comparison to other real estate companies.

5.3.2 Activity

The business developer C works with everything from organizational development, strategy work, to be involved in changes of systems, processes mapping, and process development.

IM C explains that the digital building assets are today managed by the technical information management department, where there is a dedicated information manager for each campus. The information managers are responsible for the original drawing archive including the as-built documents, being responsible for specifying the required project information deliverables, specifies the meta-data tagging of the information, publishing to the public archives. The role as an information manager also has a responsibility against the building projects where the project managers of each discipline request information.

The technical information manager C explains that their activities include responsibility for digital asset management, quality assurance of project deliveries,

responsibility of the original archive, provide space information, making sure that external and internal parties have access to the right information in the drawing archive.

5.3.3 Technology

The technical information manager C explains that the technological evolvement recently has been accelerated. The company has recently implemented a BIM delivery specification with the aim that all new projects will be delivered in BIM. The delivery specification is a guiding document that is developed by the technical information management department together with the operational team to find what the information deliverables need to carry. The BIM models need to communicate with the IWMS-system and asset database, which is connected by standardized Building Information Properties-codes (BIP-codes).

IM C explains that the company also has initiated two pilot projects where a digital twin solution has been generated from point clouds and reality capturing. The Akademiska Hus have also started to see benefits in installing IoT solutions such as motion sensors. The sensors capture how different buildings and spaces are being utilized, which rooms are being utilized the most, which rooms are not being used as often, which facilities are often booked, which facilities are often booked but not used, and much more information. Reports of the sensor data are later delivered to the customers and further creates value for them. The sensors are also connected to the digital twin where the sensors can be monitored in real-time.

5.3.4 Information

IM C believes that the architectural models are the most vital information to keep updated to a high-quality standard. This is due to the geometrical information being governing in the leasing contracts. Further, installations that have regulatory requirements need to be maintained in the asset database. IM C believes that the information needs to be operational and that the information should be based on the needs of the customers and management. A classification list has therefore been made with the installations and information that is needed. IM C, however, explains that the operational managers often are not aware of which information is needed, in those cases the technical information coordinators is acting as a supporting function towards making proposals of which information they could benefit from. The technical information manager is responsible and the owner of the information.

5.3.5 Processes

IM C explains that the company is moving very fast, and large changes have been made at a high pace and that it is difficult to evaluate if the companies processes have has been keeping up with the technological evolvement. The two pilot projects where BIM was evaluated resulted in an implementation where many of the processes have been created afterward, it shows practical examples of what processes works and which does not. There is always a risk that it creates stress within the organization when process work is being made continuously as it gets implemented, but IM C means that so far this has not been a large problem.

IM C explains that the goal is to keep the digital assets as close to the physical assets as possible and it is because of the business value, to be able to give the customers accurate service, and especially when the customers are requesting sensor data since it is dependent of the accuracy of the space. Traditionally the square meter of the space

was the only thing needed, but now the company wants to know which kind of room it is if it is a classroom, an office or an auditorium. This has been enabled through co-classification of each space and it is crucial for the sensors to read correctly.

The company has also introduced processes for laser scanning where the information gets validated against what is in the asset database. IM C explains that this is increasingly important since it needs to be up to date. But there is not a scheduled or initiating factor towards when each laser scan should be done.

IM C further explains that it is also very important to differentiate between rebuilding projects, ongoing management. For the larger projects with a dedicated project manager, laser scanning is included within the project. In the smaller management projects, where for example an operations technicians is the project manager, where there is not a dedicated designer and more of an informal procedure, the digital assets are often not updated. IM C believes that if there is a lot of these informal projects, the information quality is getting damaged and there should be processes for capturing the changes. Today there are no defined processes to capture the smaller changes, IM C explains that it needs to be looked into and that a system for managing errands and changes. In the new IWMS-system that is being implemented, there is however a way to make redlining and notes on drawings.

6 ANALYSIS AND DISCUSSION

In this chapter, the result from the case study is analyzed and discussed, starting with a comperative analysis of similarities and differences in the approach to and the organizational view of digital asset management. Further, a comparative analysis of which barrier and enablers the companies are facing in relation to the activities carried out, technological advancements, information need, and processes implemented.

6.1 Organizational view of digital asset management

The result has shown that all of the respondents have a common understanding of the importance of digital assets and their processes. Drawing on Skålén (2018) the companies sees the business benefits of creating a better knowledge of their managed properties and offering services beyond the physical properties. A common factor between all of the companies is that they understand that there is an ongoing change process happening within the company and that there is a need for more life cycle thinking, which is also noted by Dalla Valle (2021). The new digital environment has accelerated both technological as well as organizational development. The analyzed case companies have a different approach towards which strategy is to prefer and in which order the technological advancement should be made. Jernhusen has chosen to take a large digital leap in a short amount of time, such as the digital inventory project where large digital assets have been gathered, and new technologies such as a digital twin solution implemented of the majority of the property portfolio. As the technology evolves, the organization and processes are following. Västfastigheter has had a larger focus on organization and processes, by slowly moving towards replacing CAD models with BIM, rather than taking a large digital leap towards digital twins and IoT. Västfastigheter also states that there is a strong need to set a long-term goal towards where the company sees itself in the future. Akademiska Hus has both taken a larger digital leap and is parallelly built up an organization, new business models, and processes through Digital Twin projects, BIM-management, and IoT space management solutions. Akademiska Hus explains that there is a common long-term goal within the company towards working systematically with digitalization as a crucial business benefit, both practical and operational. Akademiska Hus also sees benefits in getting control over the information as it has allowed the company to easier adapt and change to new systems, for example when implementing a digital twin solution. The digital maturity within the organization of Akademiska Hus is also noted as high.

Rogers et al. (2019) explain in the Diffusion of innovation theory how actors can be categorized into different stages in to which extent and pace new technologies get adopted. In the theory, the categorization is explained as *innovators*, *early adopters*, *early majority*, *late majority*, and *laggards*. Jernhusen has expressed a strategy that is not aiming towards being an actor of innovations, mainly due to the unwillingness to take risks and keep OPEX's low. The early adopters are actors with high opinion leadership, financial liquidity, and education. Due to the characteristics and discreetness of Jernhusen's digitalization strategy, taking a large and fast leap towards an already proved technology, it might be argued that Jernhusen can be characterized as an early adopter. Västfastigheter has however not taken the digital leap towards BIM-management and digital twin solutions. Västfastigheter is yet not keen to be a driving innovator in the sector and is not willing to risk a large amount of monetary losses due to technological advancement. It can be further be argued that Västfastigheter might be

categorized as a later majority or laggard. Representatives from Akademiska Hus explain that the position taken is aiming towards being an innovative driver within the sectors. The company has implemented two full-scale digital twin solutions, implemented IoT and sensors data improving information-driven decision making for customers. Further, Akademiska Hus has initiated BIM management and has received BIM models for future life cycle maintenance. The technological leap that Akademiska Hus has taken shows risk-taking and financial liquidity which are both characteristics that define an *innovator* (Rogers et al., 2019). The proposed categorizing of the companies is illustrated in Figure 6.1.

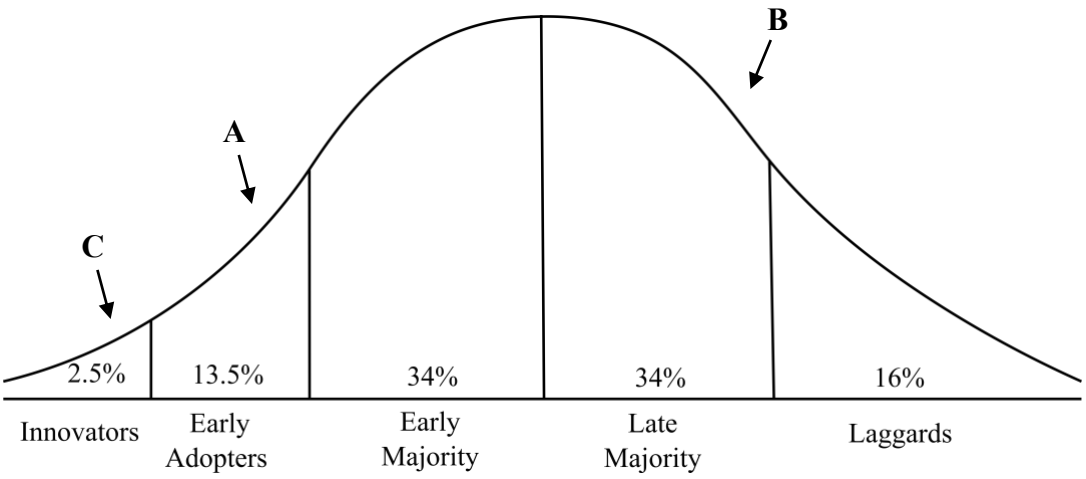
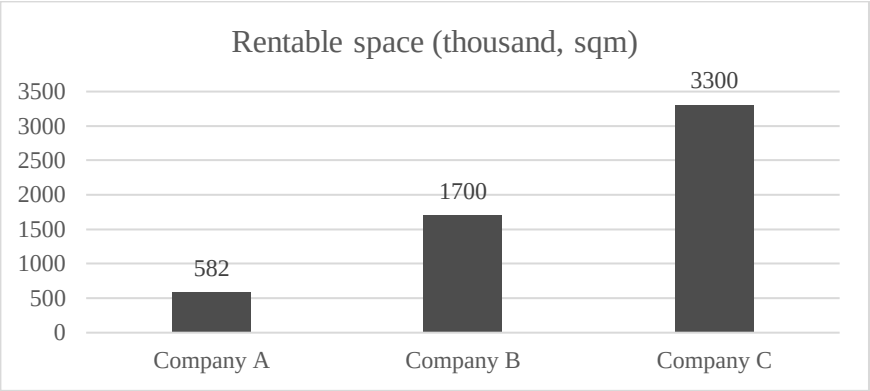


Figure 6.1: The case companies position on the innovation curve by Rogers.

It is of importance to not only take a technological leap into consideration when making a comparison between digital asset management strategies, but contextual factors have also be taken to consideration. Firstly, considerations need to be taken towards the size of the different case companies, see Table 2. Jernhusen has a significantly smaller property portfolio in comparison to Västfastigheter and Akademiska Hus, which might result in a lower amount of digital assets. Akademiska Hus has the largest property portfolio of 3.3 million sqm rentable space, whilst Västfastigheter is managing 1.7 million sqm of rentable space. Also, it is important to notice that it is not only the amount of space that is a deciding factor of the amount of digital assets. Västfastigheter's property portfolio is to a large extent consisting of healthcare facilities which often is of high complexity, where the properties' complex characteristics are increasing the informational needs.

Table 2: The amount of rentable space (thousand, sqm).



Jernhusen explains that the strategy towards digital asset management is not to be on the leading edge, and rather than being the driving innovators within the sector, the company aims towards being the best at implementing the already known technologies. The reason for choosing this strategy is explained as first, being a public actor with a responsibility to deliver a good profit margin towards the owners, being the Swedish government. Secondly, the company does not believe that the internal competencies and digital maturity is high enough to be innovators in the area of digital asset management. There are large ambitions towards utilizing the technologies that lay ahead such as increasing connectivity and smartness of the property portfolio but would rather let other actors be the driving forces of the technological evolvement, and when the solution has been verified, Jernhusen should take a large and fast leap to follow. Jernhusen has a long history of keeping a core-business mindset, meaning that the main objective is to be asset managers. Jernhusen is following the trend to refocus the business model from a goods-logic to a service-dominated logic, also presented by Skålén (2018), which may allow the company to deliver a better service to its customers. The change of business model is in direct correlation to the new digital transformation that the company is realizing. By improving the current building stocks digital assets by the large digital inventory project, shifting towards BIM-management and a digital twin solution, the company is aiming towards offering the customer a more service-dominated business.

Since the business model of Jernhusen has the main focus on core business, the organization today has an organization consisting of a smaller support function to the operational real estate management services. The support functions include the role of BIM strategist A and a similar role with a focus on the smart-property. The organization has made a choice not to have operational competencies towards the digital asset management process, instead, Jernhusen has outsourced the service. Västfastigheter has chosen to have a larger focus on the operational digital asset management process, with a larger team working operationally with receiving, updating, and maintaining the digital assets. This choice may be in direct relation to the difference in organizational size and compared to Jernhusen, the digital assets might be more extensive due to the larger property portfolio and the portfolio's nature. Akademiska Hus has a similar approach as Västfastigheter has towards building an organization around the digital asset management processes.

6.2 Enablers and barriers

As follows, barriers and enablers the companies are facing in relation to the activities carried out, technological advancements, information need, and processes implemented are analyzed and discussed.

6.2.1 Enablers and barriers in relation to Activity

Technical managers within the companies have different roles towards the digital asset management, Jernhusen has chosen to give TM A which is in an operative role, also the responsibility to be an information owner. Västfastigheter and Akademiska Hus have made a choice to build an organization with roles including roles of information managers which have information ownership and operational role towards the digital asset management process. The role of an information manager is also to be part of the different projects to assure that deliverables and quality is assured.

Kincaid (1994) mentions that there are three main characteristics of the function of building asset management, it needs to act as a supporting actor to an organization, it needs to sync strategical, tactical, and operational management with the organization's activities in order to create value, and thirdly a good knowledge about the facility and the management processes is needed to be able to support an organization efficiently. From the case study where different building asset management organizations have been investigated, the importance of these characteristics can be acknowledged. Both Jernhusen, Västfastigheter, and Akademiska Hus works as a supporting actors in different operations, Jernhusen manages public commercial properties with a focus on infrastructure and transportation, Västfastigheter manages public commercial properties with a main focus on healthcare, and Akademiska Hus manages public commercial properties with a focus on education. All three of the companies have a complex property portfolio to manage which requires the strategical, tactical, and operation management to be synchronized. Both Jernhusen and Västfastigheter have a history of being decentralized organizations where there is a large diversity of digital maturity, which may interrupt the synchronization between the different operational levels. Thirdly, the knowledge of their facility and management process is further hard to define, both Jernhusen and Västfastigheter are today managing a large amount of information and knowledge related to the managed properties.

Both Jernhusen, Västfastigheter, and Akademiska Hus mentions the crucial activities which are initiating digital asset management are projects related to space management, short- and long-term maintenance planning, energy-performance and monitoring. The technical managers within the organizations have expert knowledge in their respective areas of work. It can further be argued that it is of great importance that the technical competencies need to influence how the digital asset management activities will be executed.

Atkin & Brooks (2015) Explains how important it is to have a common strategy towards how an organization approaches digital asset management and that each role within the organization has a clear idea of which activity and responsibility are needed. The results from the interviews show that respondents from both Jernhusen and Västfastigheter lack the insight of responsibilities towards who is responsible for doing what. It might therefore be argued that it is of great importance for organizations to develop a common

policiess through using mapping tools such as RACI-matrix's and process information mapping (Atkin & Brooks, 2015; MSB, 2012; Project Management Institute, 2017).

To conclude have all companies created enabling factors according to people and roles working with digital asset management, in-house or outsourced. Identified barriers are unclear responsibilities and roles, which can further be explained by a high level of complexity of the companies' property portfolios and the level of autonomy and decentralization.

6.2.2 Enablers and barriers in relation to Technology

The technological implementation of Jernhusen and Västfastigheter is similar, both of the companies have is aiming towards using BIM-processes for digital asset management. Jernhusen, Västfastigheter and Akademiska Hus uses the new IWMS-system named Facilliate originating from the same supplier. All of the companies explain that it is still under the implementation phase and that the functionalities and enablers as explained by the provider Service Works Global (2021) are yet not fully implemented and tested.

Jernhusen has made a large leap in the digitalization process by making the digital inventory project where a large part of the property portfolio has been captured by the scan-to-BIM methodology. Jernhusen and Akademiska Hus have further chosen to implement Digital Twin solutions built upon a variety of data-sets such as point-cloud information and. Västfastigheter has initiated a pilot project where one of the health care facility has been surveyed and a BIM model been created. Compared to Jernhusen, a large inventory project has not yet been made at a larger scale. Västfastigheter is still having a large of digital assets in 2D models.

Jernhusen and Akademiska Hus have started to utilize the benefit of Scan-to-BIM and a Digital Twin solution built upon reality capture and IoT solutions. Respondents from Jernhusen explain that the new digital twin solution allows for a lot of possibilities towards effectivise the current practices. Västfastigheter sees a future in the technologies of Digital twins and IoT. Two of the companies believe that the technological evolvement of reality capture and AI will play a large part in the digital asset management processes, and further believes that handheld devices might be used for reality capture, surveying, and validation in future use-cases.

Västfastigheter explains that there is a need to develop a system that enables the outdoor environment of the properties to be managed more efficiently. Using spatial information in a GIS environment might be future studied. A barrier can be found in relation to the knowledge transferring within the built-in errand system in the IWMS-system, some of the interviews explain barriers towards how it is not seamless and that there is a need for this kind of function.

To conclude, all companies have a strong faith in technological evolution. Large investments have been made within digital tools and systems, as well as digital inventory projects. Barriers that can be found are that there is a lack of tools for capturing smaller changes in the digital asset management process. There is also a lack of tools for managing outdoor environments.

6.2.3 Enablers and barriers in relation to Information

According to the interviewees within the case companies, there is a large inconsistency towards which information different stakeholders need. The Operational management and the technical managers within both companies express that is hard to categorize which information is the most to least important to keep maintained and up to date. TM A explains that there are governmental requirements that are crucial for legal reasons, such as fire and electrical requirements. TM B also mentions that there are requirements for governing documents. All of the interviewees asked explain that architectural models with geometrical information are governing other disciplines, and are important for leasing, space management, emergency management, energy and maintenance planning. Bolshakov et al. (2020) explain the importance of taking the redundancy into account and only focus on the absolute need-to-have information in order to create an operational information model. An operational information model in the application of digital building assets is therefore needed for the case companies, where the stream of information is reduced to suit the operations. BIM A explains how approximately ten percent of the information delivered from projects is used in later stages of a building life cycle and that a lot of information is overflow.

All of the respondents agrees that there is a barrier between the supply and demand of information. One or more respondents from each of the case companies belives that a large barrier in the maintenance process of digital assets is grounded in that there is an unclarity in which the need-to-have information is. For example, BIM strategist A explains that the absolute need-to-have information could be as little as an address, maintenance plan, and the exact information. TM B explains that the need-to-have is dependent on which level of detail the management needs for a certain situation, for long-term maintenance installation type (AFF-code), a quantity or area is enough, whilst for short-term maintenance, more detailed information is needed. As explained by Ganter & Lützkendorf (2019) all of the actors both must have a knowledge and understanding of which information is needed and to which extent.

To put Ganter & Lützkendorf (2019) explanation of supply and demand in a theoretical context, the supply of information needs to be streamlined to fit the demand of information. The information is often supplied in large quantities from where the result is a lower life-cycle quality of information, due to an unmanageable information quantity. It might be argued that it is important that the equilibrium, where the supply of information meets the demanding quality and quantity is to strive for. The demand is today regulated in the delivery specifications of the companies, further, the refinement of these documents is of great importance to keep an operational information model.

All of the case companies experiences that there are no processes in place to be able to transfer the information and knowledge that is gathered from smaller construction projects, it has further been deliberated that in order for digital assets to be assessed in a project, it requires that the project is of a larger nature, due to the lack of incitements to use resources for smaller revision work to for example a BIM model. By not addressing physical changes that are being made in the digital assets, the information quality and trustworthiness is being lost over time (Ganter & Lützkendorf, 2019). Further, when the operational management, as described by the companies, is initiating smaller maintenance projects and changes which is not communicated properly to the management systems, tacit knowledge is forming information pools within the

organizations, which is described by Cárcel-Carrasco & Cárcel-Carrasco (2021) as a large organizational barrier.

Ganter & Lützkendorf (2019) defines important characteristics of an operational information model, including characteristics such as information need to be available and meet the requirements of the stakeholder at the right time. This characteristic is also recognized by the respondents which explain that a lot of the current practice is not involving information-driven decisions being made. Further characteristics include that information needs to be extracted from earlier stages in a building's life cycle, which is a large focus within the organizations due to the delivery requirements implemented. Further, information needs to have a timestamp and a designated author who is responsible for the correctness and related liabilities. This is an important characteristic that is not seen in the company due to the unclarity towards both information ownership, intellectual properties, and organizational roles and responsibilities. The respondents explain that it is of great importance to have a single point of truth in order for information to maintain reliable and of higher quality. This means that the information should only have one single source or have a master data.

To tackle the problem of information loss due to smaller changes of the physical assets during the life cycle of a building, it is acknowledged by all the companies that new processes need to be developed. Jernhusen has faith in new technologies and believe that solutions including reality-capture and handheld devices will play a large role in the processes.

To conclude, there is a common understanding that an operational information model needs to be developed and that it should include only the absolute necessary need-to-have information in order to be manageable. Old habits and traditions have however had a larger focus on the good-to-have information, becoming a barrier since it loses reliability and quality. Other factors affecting the reliability and quality of the digital assets are smaller projects are forming which are not allowing for information and knowledge to be transferred properly within the company, forming tacit knowledge.

6.2.4 Enablers and barriers in relation to Processes

There is a common view towards the importance of implementing digital asset management processes to keep high quality and reliability of information during a building's life cycle. As explained there is a concern within the digital asset management processes and updating of as-is-information, where there is an uncertainty towards who is responsible for what activity. Atkin & Brooks (2015) explains that in case of alteration and changes to the physical assets, there needs to be processes and procedures for collecting, analyzing, storing, and updating the as-is-information and that it is stated within the owners of the assets information strategy. Respondents from Jernhusen believe that technology often is not the main barrier for digital change processes, BIM A is keener to focus on the organizational barriers that are present in the company. The main take is that the organization has not yet defined a process that is allowing the quality of the information to be held during a building's life cycle. Västfastigheter believes that processes and routines are the pillars of a working information model. Akademiska Hus further explains that the company is moving very fast, and large changes have been made at a high pace, and it is resulting in that it is difficult to evaluate if the companies processes have has been keeping up with the technological evolvement.

All three companies explain that there are today no processes that are capturing the smaller changes and updating the as-is information models as explained by (Atkin & Brooks, 2015). The companies's explains that it is often very hard to find incitements to update digital assets due to smaller maintenance work. For example when there are smaller installation changes, renovation work, and remedial maintenance. This is due to that these kinds of projects does not have a designated project organization where as-built deliveries is included in the project budget. Therefore, new processes need to be developed to transfer both the information and tacit knowledge towards the digital assets. Attempts have been done by Västfastigheter to use analog methods to pile up smaller changes which later are updated in the digital assets. This method however requires a lot of organizational motivation and can be seen as primitive.

Jernhusen and Akademiska Hus have started to see the benefits in Digital Twin solutions which are based on point-cloud-data and reality capture. Point-cloud-data is a static information format that is not easily adapted to minor changes since it requires a scanning process to be initiated, often by an external party. As of now the digital twin solutions are not integrated with interoperability towards IWMS-system that the companies recently implemented, creating an unwanted barrier towards the single-point-of-truth. The static information barrier requires that there is regulatory re-scanning being done which might be initiated due to a loss of information reliability and quality of the digital twin. It is important to notice that the digital twin solutions are in an early stage of development and that in the future, sensor nodes and connectivity might result in self-updating digital twins which reflects any alterations made to the physical asset as described by (Poli et al., 2020). Akademiska Hus describes that there is a current aim towards utilizing validating tools to sense alterations in the point clouds.

An example is the main system illustrated in a simplified system architecture overview in Figure 6.2. The ruling information is stored in an asset database, which is an extension of the newly implemented IWMS-system. The IWMS-system as well as the asset database is where the main non-geometrical information is stored and is utilized by the different operations in the organization. The asset database communicates and gathers information from the BIM models which are either generated reality capture in the digital inventory project or from project deliveries. The digital inventory project has allowed for the existing building stock to be surveyed and modeled through a Scan-to-BIM process. The digital inventory project has been a collaboration between the organization and external consultancy, where 3D scanning has been utilized to gather a point cloud. By embedding the captured point cloud in a cloud based Digital Twin platform, more value has been added for the organization. For new construction projects, the BIM deliverables is set and required in the procurement of a project. This allows the organization to continuously receive as-built models with the requested attributes, BIM-standard, and quality. Further, the information received in the BIM model is extracted to the asset database for future maintenance and to achieve a single point-of-truth.

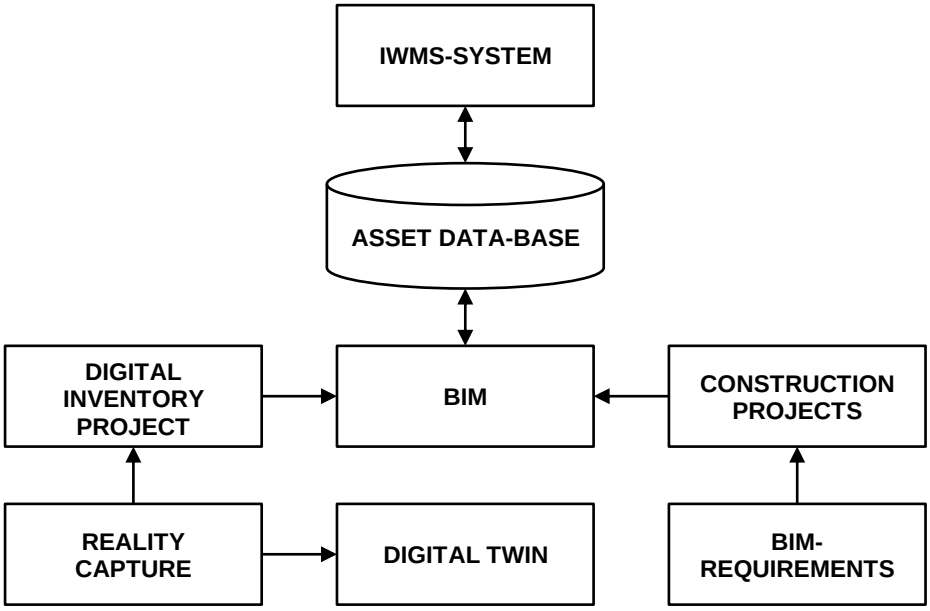


Figure 6.2: The current asset-management architecture.

7 CONCLUSION

The objective of this comparative case study was to explore how three different companies in the real estate sector approach and organize digital asset management in the use and operational phase of a building's life cycle, and what barriers and enablers they are facing in relation to activity, technology, information, and processes. The following research questions were guiding the study:

- How do property owners approach and organize digital asset management in the use and operational phase of a building's life cycle?
- Which enablers and barriers are property owners facing in the strive of having high quality and reliability of their digital assets during the use and operational phase of a building's life cycle?

The result showed that all three companies have a common understanding that there is a digital change process that is needed to be adapted to in order to work efficiently with real estate management. However, the three companies have chosen different approaches towards the change process mainly due to contextual factors such as organizational size, digital asset portfolio, digital maturity, and business model. They have also chosen different strategies to organize for digital asset management.

In Table 3 the results from the second research question are summarized, showing what enablers and barriers are property owners in the real estate sector facing in the strive of having high quality and reliability of their digital assets during the use and operational phase of a building's life cycle.

Table 3: Summarize of results.

	Activity	Technology	Information	Processes
Enablers	Persons and roles designated to work with digital asset management activities.	Large faith in technology. Large digital investments. Digital Twins allowing for real-time data and IoT. BIM allowing for life cycle thinking.	A large supply of information. Aim towards an operational information model.	Strive towards implementing digital maintenance processes. Scan-to-BIM methodology to capture information.
Barriers	Unclear responsibilities and roles. The complexity of the property portfolio. High level of autonomy and decentralization.	Lacking tools for notifying smaller changes, such as an errand report system. Digital tools for managing the outdoor environment.	Low focus and clarity towards what is need-to-have information. Old habits and traditions. Low reliability in information. Tacit knowledge being trapped in the organization.	Lacking processes for assuring information quality. Interoperability issues between systems. The DT solution needs to adapt to alterations of the physical asset. Processes including the use of an errand system are needed.

The question of how changes due to renovations and alterations is are to be transferred into the operational model is further to be investigated. A potential solution is to implement a digital errand system with the following criteria, with the inspiration from interviews:

- It needs to be seamless and easy to use to minimize the activity of errand reporting being interrupted.
- It should communicate to an IWMS-system and an addressed information manager.
- It should be accessible to use with a hand-held device i.e. smartphone or tablet.
- It should allow all actors to capture alterations and create a co-creation of value.
- Provide feedback and create incitements to be used.

A possible solution could also include utilizing a building passport-solution as proposed by Ganter & Lützkendorf (2019) and Sesana & Salvalai (2018), where information regarding a building historical changes is creating a unique building logbook where older building information is stored in chronological order, as compared to a vehicle-database. This study has not focused on how the companies use standards as ISO 19650, which is suitable for digital asset management. A recommendation for further studies will then be to explore this. Implementation of the ISO 19650 standard might guide the companies in the change processes towards BIM management.

To conclude, there is a common view that processes need to be developed. Smaller changes are not captured in the current practices. There needs to be a focus on interoperability between different systems and technologies. The digital twin solution needs ways to easily adapt to alterations of the physical asset. Processes enhancing life cycle quality and reliability in the digital asset management process need to be further developed together with a new technological solution such as an errand system. Drawing on the result of the study, a number of recommendations can also be made to companies working with digital asset management:

- There needs to be a clear vision and strategy towards how the company works with digital asset management in the future (Atkin & Brooks, 2015).
- A clear organizational structure where roles, information owners together with competencies are stated (Atkin & Brooks, 2015; Project Management Institute, 2017).
- The operational management has to unite towards which information is the need-to-have information and develop project delivery requirements (Ganter & Lützkendorf, 2019).
- Information flows, master data and system interoperability needs to be mapped through process mapping (Ganter & Lützkendorf, 2019).
- Processes need to be developed to capture smaller alterations made in the physical asset, as well as new technologies (Atkin & Brooks, 2015).
- Routines for follow-up cases, reouccuring validation, and digital inventory projects need to be developed (Cárcel-Carrasco & Cárcel-Carrasco, 2021).

8 REFERENCES

Al-Fedaghi, S., & Al-Azmi, F. (2011). Evolution of data into an information hierarchy. *Journal of convergence information technology*, *6*(2), 9–21.

Atkin, B., & Bildsten, L. (2017). A future for facility management. *Construction Innovation*, 17(2), 116–124. https://doi.org/10.1108/CI-11-2016-0059

Atkin, B., & Brooks, A. (2015). *Total facility management* (4th. ed.). Wiley Blackwell.

Azizi, S., Nair, G., Rabiee, R., & Olofsson, T. (2020). Application of Internet of Things in academic buildings for space use efficiency using occupancy and booking data. *Building and Environment*, *186*(107355). https://doi.org/10.1016/j.buildenv.2020.107355

Becerik-Gerber, B., Jazizadeh, F., Li, N., & Calis, G. (2012). Application areas and data requirements for BIM-enabled facilities management. *Journal of construction engineering and management*, *138*(3), 431–442. https://doi.org/10.1061/(asce)co.1943-7862.0000433

Bjälnäes, P. (2016). *Fastighets- och servicesystem*. Sveriges kommuner och landsting.

Bolshakov, N., Badenko, V., Yadykin, V., & Celani, A. (2020). As-built BIM in real estate management: The change of paradigm in digital transformation of economy. *IOP Conference Series: Materials science and engineering*, *940*(1), 012017. https://doi.org/10.1088/1757-899X/940/1/012017

Boverket. (2020). *Miljöindikatorer 2019 - en sammanställning av de texter som publicerats på boverket.se*. *21*(1), 1–9.

Bryman, A. (2015). *Social research methods*. Oxford University Press.

Carbonari, G., Stravoravdis, S., & Gausden, C. (2018). Improving FM task efficiency through BIM: a proposal for BIM implementation. *Journal of corporate real estate*, *20*(1), 4–15. https://doi.org/10.1108/JCRE-01-2017-0001

Cárcel-Carrasco, J., & Cárcel-Carrasco, J. A. (2021). Analysis for the knowledge management application in maintenance engineering: Perception from maintenance technicians. *Applied Sciences*, *11*(2), 703. https://doi.org/10.3390/app11020703

Dalla Valle, A. (2021). *Change Management Towards Life Cycle AE(C) Practice*. Springer International Publishing.

Dejaco, M. C., Re Cecconi, F., Moretti, N., Mannino, A., & Maltese, S. (2020). Building and district data organization to improve facility and property management. In B. Danniotti, M. Gianinetto, & S. Della Torre (Eds.), *Digital transformation of the design, construction and management processes of the built environment* (pp. 255-265). Springer. https://doi.org/10.1007/978-3-030-33570-0_23

di Giuda, G. M., Pattini, G., Seghezzi, E., Schievano, M., & Paleari, F. (2020). The construction contract execution through the integration of blockchain technology. In B. Danniotti, M. Gianinetto, & S. Della Torre (Eds.), *Digital transformation of the design, construction and management processes of the built environment* (pp. 27-36). Springer. https://doi.org/10.1007/978-3-030-33570-0_23

EFCA. (2018). BIM and ISO 19650 from a project management perspective [Booklet]. https://www.frinet.dk/media/1307/381783_efca_flipbook_bim_fri.pdf

Eriksson, L. T., & Wiedersheim-Paul, F. (2014). *Att utreda forska och rapportera* (10th ed.). Liber AB.

European Commission. (2020). *Digital Economy and Society Index (DESI) 2020: Integration of digital technology*. 16. https://digital-strategy.ec.europa.eu/en/library/digital-economy-and-society-index-desi-2020

Fastighetsägarna. (2018). *Digitalisering och mobilitet: Ett förändrat affärslandskap för fastighetsbolag väntar runt hörnet*. https://www.fastighetsagarna.se/globalassets/rapporter/stockholms-rapporter/digitalisering-och-mobilitet.pdf

Fastighetsägarna. (2021). *Fastighetsbranschen i korthet*. https://www.fastighetsagarna.se/fakta/fastighetsbranschen-i-korthet/

Ferreira, J., Mueller, J., & Papa, A. (2018). Strategic knowledge management: Theory, practice and future challenges. *Journal of Knowledge Management*, *24*(2), 121–126. https://doi.org/10.1108/JKM-07-2018-0461

Finansinspektionen [The Swedish Financial Supervisory Authority]. (2019). *Den kommersiella fastighetsmarknaden och finansiell stabilitet*. https://www.fi.se/contentassets/f0b2175448734d998679a33d8eaf8f6e/komm_fastighet_finstab.pdf

Ganter, M., & Lützkendorf, T. (2019). Information management throughout the life cycle of buildings - Basics and new approaches such as blockchain. *IOP Conference series: Earth and environmental science*, *323*(1), 12110. https://doi.org/10.1088/1755-1315/323/1/012110

Gao, X., & Pishdad-Bozorgi, P. (2019). BIM-enabled facilities operation and maintenance: A review. *Advanced engineering informatics*, *39*, 227–247. https://doi.org/10.1016/j.aei.2019.01.005

Hammond, M., & Wellington, J. (2021). *Research Methods; The Key Concepts (2nd. Ed.)*. Routledge.

IBM. (2021, March 15). What is a digital twin? 2021. https://www.ibm.com/topics/what-is-a-digital-twin

IFMA. (2021). *What is Facility Management?* https://www.ifma.org/about/what-is-facility-management

Jernhusen. (2020). *Fastighetsförteckning Jernhusen 2020*. https://www.jernhusen.se/globalassets/dokument/fastighetsforteckning/jernhusen-fastighetsforteckning-20192.pdf

Kincaid, D. (1994). Integrated Facility Management. *Facilities*, *12*(8), 20–23. https://doi.org/10.1108/02632779410062353

Koch, C., Hansen, G. K., & Jacobsen, K. (2019). Missed opportunities: two case studies of digitalization of FM in hospitals. *Facilities*, *37*(7/8), 381–394. https://doi.org/10.1108/F-01-2018-0014

Lekander, J. R. G. M. (2015). Real estate portfolio construction for a multi-asset portfolio. *Journal of Property Investment & Finance*, *33*(6), 548–573.

Mahdjoubi, L., Moobela, C., & Laing, R. (2013). Providing real-estate services through the integration of 3D laser scanning and building information modelling. *Computers in Industry*, *64*(9), 1272–1281. https://doi.org/10.1016/j.compind.2013.09.003

Maslesa, E., & Jensen, P. A. (2019). Managing environmental building performance through IT systems. *Facilities*, *38*(3–4), 235–251. https://doi.org/10.1108/F-01-2019-0013

McKinsey. (2017). *Möjligheter för Sverige i digitaliseringens spår*. https://www.mckinsey.com/~/media/mckinsey/featured%20insights/europe/mojligheter%20for%20sverige%20i%20digitaliseringens%20spar/digitizing-sweden-mojligheter-for-sverige-i-digitaliseringens-spar.ashx

MSB. (2012). *Vägledning för processorienterad informationskartläggning*. https://rib.msb.se/filer/pdf/26410.pdf
Nordstrand, U. (2008). *Byggprocessen* (4th ed.). Liber AB.
Nyvlt, V. (2020). BIM within current building facilities and infrastructure. *IOP Conference series: Materials science and engineering*, *972*(1), 012040. https://doi.org/10.1088/1757-899X/972/1/012040
Peng, C. (2016). Calculation of a building's life cycle carbon emissions based on Ecotect and building information modeling. *Journal of Cleaner Production*, *112*, 453–465. https://doi.org/10.1016/j.jclepro.2015.08.078
Pöchtrager, M., Styhler-Aydln, G., Döring-Williams, M., & Pfeifer, N. (2017). Automated reconstruction of historic roof structures from point clouds – developments and examples. *ISPRS Annals of the photogrammetry, remote sensing and spatial information sciences*, *4*(2W2), 195–202. https://doi.org/10.5194/isprs-annals-IV-2-W2-195-2017
Poli, T., Mainini, A. G., Speroni, A., Cadena, J. D. B., & Moretti, N. (2020). The effect of real-time sensing of a window on energy efficiency, comfort, health and user behavior. In B. Daniotti, M. Gianinetto, & S. Della Torre (Eds.), *Digital transformation of the design, construction and management processes of the built environment* (pp. 291-296). Springer.
Pomè, A. P., Tagliaro, C., & Ciaramella, G. (2021). A proposal for measuring in-use buildings' impact through the ecological footprint approach. *Sustainability*, *13*(1), 1–21. https://doi.org/10.3390/su13010355
Project Management Institute. (2017). PMBOK® Guide Sixth Edition (PMI, 2017). In *Project Management Institute* (Vol. 6). http://www.citeulike.org/group/14887/article/9008974
Re Cecconi, F., Dejaco, M.C., Moretti, N., Mannino, A., & Blanco Cadena, J.D. (2020). Digital asset management. In B. Daniotti, M. Gianinetto, & S. Della Torre (Eds.). *Digital transformation of the design, Construction and management processes of the built environment* (pp. 243-253). Research for Development. Springer. https://doi.org/10.1007/978-3-030-33570-0_22
Rogers, E. M., Singhal, A., & Quinlan, M. M. (2019). Diffusion of innovations. In E.M. Rogers, A. Singhal, & M.M. Quinlan (Eds.), *An integrated approach to communication theory and research* (3rd. ed.). https://doi.org/10.4324/9780203710753-35
Saiful Bahri, M. A., Abdul Maulud, K. N., Rahman, M. A., Ridzuan Oon, A. O., Che Ani, A. I., Che Hashim, C. H., Karim, H., Hasbullah, M. S., & Aziz, M. Z. (2019). Development of GIS database and facility management system: Asset and space in UKM. *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences - ISPRS Archives*, *42*(4/W16), 563–571. https://pdfs.semanticscholar.org/00fe/6e46c98dd8d89a8bdae286650d5e95c0304f.pdf
Service Works Global. (2021). *Integrated Workplace Management System*. https://www.swg.com/se/programvaror/integrated-workplace-management-system-iwms/
Sesana, M. M., & Salvalai, G. (2018). A review on building renovation passport: Potentialities and barriers on current initiatives. *Energy and Buildings*, *173*, 195–205. https://doi.org/10.1016/j.enbuild.2018.05.027
Silverman, D. (2015). *Interpreting qualitative data* (5th. ed.). SAGE.
Skålén, P. (2018). *Service Logic*. Studentlitteratur AB.

Stake, R.E. (2000). Case Studies. In N. Denzin & Y. Lincoln (Eds.). *Handbook of qualitative research* (2nd. ed.) (pp. 435-454). SAGE.

Sternik, S. G., & Teleshev, G. V. (2018). Impact of Banking real estate as an asset class on financial system stability: Monitoring, forecasting, management. *Journal of Reviews on Global Economics*, *7*, 851-864. https://doi.org/10.6000/1929-7092.2018.07.83

Swedish research council. (2017). *Good research practice.* https://www.vr.se/download/18.5639980c162791bbfe697882/1555334908942/Good-Research-Practice_VR_2017.pdf

Teicholz, E. (2001). *Facility Design and Management Handbook*. The McGraw-Hill companies.

Wang, Q., Guo, J., & Kim, M. K. (2019). An application oriented scan-to-BIM framework. *Remote Sensing*, *11*(3), 365. https://doi.org/10.3390/rs11030365

Zins, C. (2013). Conceptual approaches for defining data, information and knowledge. Journal of the American Society for Information Science and Technology, 64(July), 1852-1863.

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