
Developing a BIM-based Framework to Support Sustainable Facility Management Processes

Master's Thesis

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CONREM

from

Ahmed Aziz

S0572701

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1st Supervisor: Architect Eric Pollock

2nd Supervisor: Dr-Ing. Markus Krämer

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.....

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Copy of proposed conceptual formulation



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HTW Berlin Registration Number: **S0572701**

Surname: **AZIZ**

First Name(s): **AHMED**

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BACKGROUND

The demand of Building Information Modelling (BIM) has been increasing in the last few decades. Many governmental and private institutions have been shifting to BIM, particularly in promoting buildings' life-cycle management. Although the implementation of BIM requires in-depth technical knowledge and might have many methodological, BIM promises to support efficient Information Management (IM) in Facilities Management (FM). Additionally, adopting BIM in FM has the potential to improve quality of life (QOL) in the built environment. BIM encompasses multiple discipline to ensure higher systems' functionality by integrating people, place, processes and technology in a form of a holistic framework. The present research aims to identify Key deficiencies in the FM marketplace, and contextual barriers against formulating/implementing such a framework.

Literature indicates that as much as the demand/use of BIM is increasing rapidly, stakeholders don't seem to consider it as an all-inclusive system, instead, BIM is reportedly used in only parts of buildings' design processes. This approach results in an overly narrow focus of the BIM-based agenda, preventing consideration of the broader benefits such practice could present through an integrative design (e.g., smart, iterative, timely process), construction (e.g. waste management, safety), operation (e.g., efficient maintenance cycles) and disassembly (e.g., reuse and recycle of materials) strategic frame. All of which will be thoroughly explored in this research.

RESEARCH QUESTIONS

Although there is gathering evidence of the financial and environmental benefits of sustainable practices in existing and new buildings, there is still perception of high cost to achieve high performance, or "green" constructions. That concern is indeed justifiable, and the construction industry can be forgiven if struggles to take sustainable development on board since there is shortage of sound guidance on what the concept means [for construction] on the long-term and what the industry would have to do to achieve it." Within this context, the focus of this research is divided into three sections. 1) characteristics, 2) potentials, and 3) framework for action. Each section raises a set of questions, leading to the main research questions explained in section 3.

1. what are the links between BIM and Facility Management in existing buildings? What are the links between FM and sustainable buildings operations and management?
2. How can BIM frameworks be integrated and implemented in order to reduce operational GHG emissions through facility management?
3. What are the future policies and procedures for FM development?

RESEARCH METHODS

A qualitative approach to sustainable facility management will be adopted in this research. Coyle (2000) suggests that qualitative research approach has five general purposes: to simplify a complex problem, to facilitate discussion by showing the relationships between the items being discussed, to help explain behaviour and generate insights, to help identify the wider context of a topic and to provide the basis for further quantitative research, if deemed essential. The issues of BIM, FM and sustainability will be discussed primarily in the global context of buildings. In thoroughly investigating the research problem, the research will draw upon multiple research methods to critically assess the status quo, pursue better clarity and applicability of facets and concepts of BIM in contemporary building design – using case study and survey methods (refer to section 2 of research questions) to illuminate best practices and identify future potential – and in response synthesizes a conceptual BIM-based framework for sustainable facility management processes. Figure 1 summarizes the qualitative research methods adopted in this research, while the next sections elucidate each method in more details.

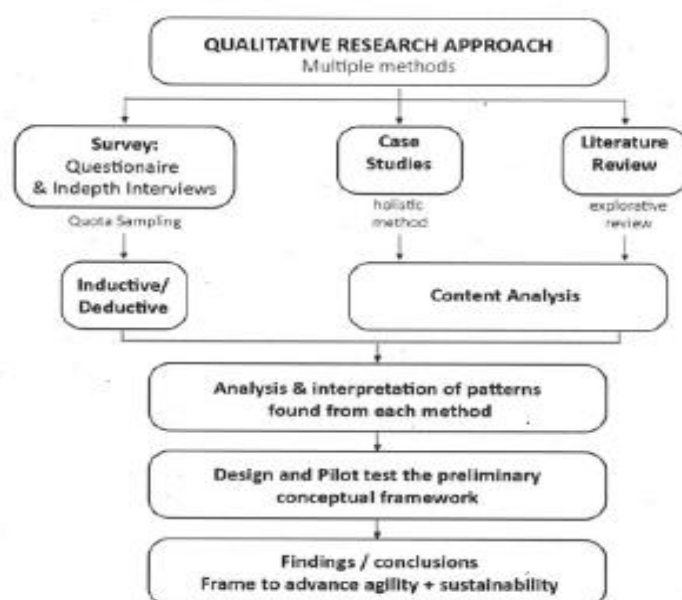


Figure 1. Qualitative research methods and process

SCHEDULE TIMELINE

Time	Milestone
July 2020	Start
September 2020	Finalize literature review
	Finalize survey design
December 2020	Secure the target population
	Collect responses from target population (facility managers)
	Feedback for the case studies chapter
March 2021	Analyse survey responses
	Finalize the case studies chapter
May 2021	Finalize the survey chapter
	Final feedback for the conclusions chapter
JULY 2021	Pilot test the preliminary framework
	Finalize the conclusions chapter
	Develop the final framework
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Signature of the Supervisor

Eric Pollock



Abstract

The cornerstone of any megastructure's key success is its sustainability throughout the years. Whether it is a building or an infrastructure network, every structure constantly faces new and increasing challenges in almost every aspect of construction, maintenance, and finally, in the demolition stage. Thus, for most parts, a prototype is a must before moving to the facility management phase. Building Information Modelling (BIM) offers a unique window for building sectors to create such predictive prototypes in the construction stages followed by an operation stage. However, BIM implementation has not passed the early construction stage yet, further showing how a prototype is mainly a must before moving to facility management, somewhat contrary to popular belief. This limited usage is generally strict because BIM is explicitly an advanced design and visualization method. Even though the development phase and life cycle are mostly the cornerstones of any construction, BIM allows for more manageable and more efficient stages. Thus, the scope of this research is not only to highlight the advantages and the effectiveness of the BIM-IoT integration but also from the facility managers' perspective and how valuable and efficient this integration.

In this manner, combining BIM with real-time data extracted from the Internet of Things (IoT) offers a dynamic paradigm for particularly practical and efficient construction and operational efficiencies. Furthermore, IoT sensor networks provide accurate real-time data streams to BIM models in numerous utilizations, besides showing how. In this manner, combining BIM with real-time data extracted from the Internet of Things (IoT) offers a dynamic paradigm for practical construction and operational efficiencies. However, despite the initiatory integration between BIM and IoT, there is still an urge to understand the present condition of BIM and IoT device integration, showing how this limited usage is strict because BIM is primarily an advanced method of design and visualization. Therefore, the fundamental purpose is to set a synchronized technique for the construction activities post the designing stage via BIM, especially under the new era of COVID-19 and its consequences.

Consequently, BIM-IoT integration in facility management is the new way of sustaining an efficient operation phase in the construction sector. According to the prior studies and the results from the survey conducted, the BIM-FM integration is the new way to maintain sustainability.

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List of Abbreviations

AEC	Architecture, Engineering, and Construction
AI	Artificial Intelligence
AIR	Asset Information Requirements
API	Application Programming Interface
BAS	Building Automation System
BDS	Building Description System
BEP	BIM Execution Plan
BIM	Building Information Modeling
BLCCE	Building's Life Cycle Carbon Emissions
BMS	Building Management System
BPM	Building Product Model
CAD	Computer-Aided Design
CAFM	Computer-Aided Facilities Management
CE	Carbon Emissions
CEC	Carbon Emissions Coefficient
CMMS	Computerized Maintenance Management System
COBie	Construction Operations Building Information Exchange
DfS	Design for Safety
DLC	Downloadable Content
EDMS	Electronic Document Management System
ETISCCP	Civil Engineering School (ETSICCP) at the Universidad Politécnica de Madrid
EMS	Energy Management Systems
FM	Facilities Management
GHG	Greenhouse Gases
GLIDE	Graphical Language for Interactive Design
GPS	Global Positioning System
GUID	Globally Unique Identifier
GWP	Global Warming Potential
HVAC	Mechanical and Engineering: Heating, Ventilation, and Air Conditioning
ICT	Information and Communications Technology
ID	Identity Names
IEE	Initial Embodied Energy
IEEE	Institute of Electrical and Electronics Engineers
IEQ	Indoor Environment Quality

IFC	Industry Foundation Classes
LCA	Life Cycle Assessment
LCEE	Life Cycle Embodied Energy
IFMA	International Facility Management Association
IoT	Internet of Things
MEP	Mechanical, Electrical, and Plumbing
MEPFP	Mechanical, Electrical, Plumbing, and Fire Protection
MSR	Minimum Sample Requirements
NBIMS	National Building Information Model Standard
OE	Operational Energy
O&M	Operation and Maintenance
PAS	Service and Administration Personnel
PFMI	Property and Facility Management Innovators
PIR	Project Information Requirements
PPM	Parts Per Million
PtD	Prevention through Design
REE	Resting Energy Expenditure
RFID	Radio Frequency Identification
SFM	Sustainable Facility Management
SQL	Structured Query Language
UPM	Higher Technical School of Civil Engineers
VAV	Variable Air Volume
WSN	Wireless Sensor Network

1. Introduction

Buildings and infrastructures are symbols of civilization. Since the dawn of time, man has sought shelter refuge in caves, but with society's evolution, people's demand for means of comfort vis-a-vis security increased. Therefore, all sorts of civil facilities are constantly developing. The timeline of civilization's megastructures is remarkable. For instance, the Pyramids of Giza, Hatshepsut's obelisk, the Great Wall of China, the Colosseum, St Paul's Cathedral, Istanbul's Hagia Sophia, Burj Khalifa, and the list goes on and on with the technological breakthrough in constructions. After World War II, technological development has experienced a qualitative leap and even more in data visualization. The growth and development of the industrial sector — especially the construction sector — witnessed a rapid boom in the last century. The development of the industrial sector increased rapidly in the previous century. With the increase in worldwide population and globalization, people continuously want modern, up-to-date dimensions, whether as houses, workspaces, or social spaces. Thus, global trade is up against the perfect competition, increasing demand for quality versus the high supply and demand price. In addition, corporations focus on reducing waste, recycling, environmental issues, and efficiency in every production and construction management phase.

Building Information Modelling (BIM) is a creative 3D model-based process that enables the construction designers and engineers the insights and tools needed to efficiently design, construct, and maintain buildings and infrastructures. BIM was an initial abstract in "Building Product Models," written by Charles M Eastman. Eastman developed his idea by "architectural modeling of information, effective models and data exchange." (Tang et al., 2019). Eastman has built BIM as a model for performance, quality management, and timetable adherence (Azhar, 2011; Eastman, 1999). In the simulation, feasibility tests, production, or maintenance of building works in engineering or architecture, BIM focuses on virtual reality alone. In addition to the function of BIM in the classes of the industrial foundation (IFC), a coherent order of systems is established by distinguishing different domains. Thus, achieving the goal of any project, especially in construction, cost-effectiveness, adhering to the schedule, and quality control while maintaining the minimum cost and time in maintenance later (Golabchi et al., 2016). BIM has increased its popularity by representing a reliable prototype in

developing enhanced project delivery practices. (Azhar, 2011; Eastman, 1999). BIM, as mentioned in more accurate, especially when dealing with facility management. Facility management covers the post constructing aspects like functionality and the efficiency of the infrastructure and buildings. Facility management efficiency and effectiveness can be measured in multiple ways. For instance, how well is the communication level between departments and the phases; building sustainability, especially in emergencies; real estate value (Booty, 2009).

BIM has become a crucial mechanism for upgrading project delivery practices with accuracy and efficiency. Comparing projects using BIM usage, BIM projects have indicated outstanding accuracy and unique identifiable building component data with many comprehensive data. This can be achieved using IoT. IoT is the interrelationship between various platforms sharing censored and actuating information in a framework for more effortless innovative applications. IoT has caused a creative window for sensor identification, recognition technologies, storing technologies, and mechanisms. In addition to the revolution in information technologies, applications, and algorithms. Besides, information processing solutions, control, and energy efficiency, and the list of advancements continue. IoT secures the most substantial advantage of the modern technological revolution and establishes a leading subset in intelligent devices, whether an intelligent appliance or various sensors and actuators. Thus, data from multiple sources are collected and organized for better analysis and interpretation.

IoT and BIM's interdependence has not been a long-standing relationship, yet it is developing and booming. BIM and IoT can be operated and monitored in numerous ways. For instance, APIs, RFID (Radio Frequency Identification) labels, databases connected to the structure, or exporting mechanics via open standards. Even though BIM and IoT are being used in various fields like smart metering, building supervision, and occupational safety and health; yet, until now, it still has a long way to develop from theory and prototype for day-to-day effective and efficient usage. In this manner, the integration and use of BIM and IoT are changing human-technology interaction and welfare now and in the future (Gubbi et al., 2013; p. 1654). This development can be utilized via synchronizing IoT devices and BIM.

1.1 Background

The built environment's ability to respond to evolving uses and tastes over time is one of the most often debated engineering topics. Cities have their souls on their own and refrained from having a static function. Cities evolve according to their current cultural diversity and differences. So, designing buildings' constant challenge allows buildings to adapt and have a window for technological updates that help absorb the occupants' changing lifestyles and patterns. In this manner, real estate decisions would characterize the holistic method to worthwhile investment and build sustainable cities only if buildings are built to address current and future problems (Imam & Sinclair, 2018).

1.1.1 Facility Management feasibility using BIM and IoT

The present research defines Facility Management (FM) as managing the building performance by integrating people, place, process, and technology to ensure the efficiency of the building environment. "FM aims to provide ultimate interaction between human intellect and technological efficiency, as well as accuracy.

Building information modeling (BIM) is a method for creating and managing digital representations of physical and functional aspects of places backed by various tools, technologies, and contracts.

The Internet of Things (IoT) is a network of physical objects—also known as "things"—embedded with sensors, software, and other technologies to communicate and exchange data with other devices and systems via the Internet.

Digital developments have profoundly altered our relationship with the urban world. Mobile devices allow quick access to and sharing of knowledge. With the framework of infrastructure, these innovations affect both implementations of infrastructure projects and day-to-day operations. The broad range of hard and soft facility administration FM operations has become widespread with computer-aided facility management (CAFM) systems. Via sensor networks and IoT apps, FM teams now have better access to a wider variety of building knowledge in real-time. Mobile applications and cloud-hosted file systems further improve these functions, giving service engineers on-site access to the data about buildings and facilities and building residents a limited

selection of self-service activities for building occupants, such as real-time room monitoring and troubleshooting. (Imam & Sinclair, 2018).

In other words, the sort of developments that may take place in the 21st century might be different from what happened in the past. Even the rate of transition in the next few decades could be substantially greater. Hence, the problem is not the ability to anticipate the future but the mechanism to build an adaptable capacity.

While FM-enabled BIM (FM-BIM & IoT) advantages are well-established, substantial barriers exist in existing buildings in which constructed geometry is usually inaccessible (Volk et al., 2014). Despite the insufficient number of case studies, most research focuses on the bridge between BIM and buildings highlighting building phases, monitoring, and generating a model with minimal research in different project stages (Chen et al., 2015).

1.1.2 Long term Sustainability

The overlapping interpretations of flexibility and adaptability require diverse approaches. In general, scientists and technologists use the word adaptive for physical changes and adaptable non-physical changes (Estaji, 2017, p. 37).

FM-BIM offers organizational advantages such as utility cost savings, comfort control, room utilization, and increased inventory management, and it facilitates enhanced FM activities by simulation and analysis capabilities. A BIM with extremely accurate details combined with shop layouts and operation and maintenance (O&M) manuals is a frequently mentioned aim of the building process to include the required feedback to support facilities management operations.

The design and maintenance of a building consume a lot of resources and materials. Through integrating BIM & IoT in FM usually refers to the method of reducing material and energy consumption. A lot of electricity and material can be avoided if a building serves its current function and can also fulfill potential needs to some degree. As a result, the most difficult challenge in architecture is actively managing the evolving demands and specifications. To meet such evolving requirements, buildings need an adaptive framework to link functionality and sustainable development configurations.

The Civil Engineering School (ETSICCP) at the Universidad Politécnica de Madrid's technology maintenance was the subject of the BIM model. As a result, the BIM model is required to host a significant volume of data and provide valuable information relevant to revised drawings (Becerik-Gerber et al., 2012) quality control, space and energy management, or emergencies (Arayici, 2008). BIM improves its performance in this context by incorporating emerging technology such as IoT, connecting and integrating with databases, or associating the model with 3D scanning data. Combining such disproportionate process methods and techniques based on the established incompatibility of the data produced ontological problems are created.

1.2 Research Problem

Since the evolution of cities and their architecture, buildings since the 1920s are now obsolete. They have a declining real estate rate as these buildings were influenced by the modern movement's functionalist design approach (Kendall, 1999, p. 753). Owing to their strict value-engineered requirements and inability to be updated to suit current needs, these structures were statically built to meet the expectations of operation at the time and are therefore not destined for occupants' optimal uses and need expensive refurbishment. This issue stems from a wrong attitude within the architecture world, which has led many to think that our cities are static objects made up of completed and single-use structures and facilities.

While the advantages have been achieved, many obstacles hindered the universal use of BIM in facility management. As a result, less than 10% of BIM is used for repair and servicing (Eadie et al., 2013). FM-BIM case studies on existing installations are minimal, but the results are all the same. Namely, 32 modeled university buildings of a total area of over 120,000 m² highlight significant issues, including the detection of information needed and tackle three questions: what information, when, and who provides it (Kassem et al., 2015). Simultaneously, some research discussed development models (housing surveys and generation of built-in BIM), knowledge sharing, interoperability, integrating and accessing BIM are some of the top critical priorities from BIM in building administration and renovation (Ilter & Ergen, 2015). Some scholars established that the critical obstacles to BIM acceptance in their FM practices are initial start-up expenses, operating costs, and the lack of BIM facility templates.

The above limitations/ barriers are consistent with FM-BIM broader literature review. The following barriers can be outlined as defining essential knowledge needed the high degree of commitment to; develop, sustain BIM, as well as BIM and FM pairing information.

The data needed to increase organizational efficiency in a building is essential to define appropriately. Given the initiative to compile and retain an operational data model, there is no restriction to data types that could be added. Still, it should be kept as low as possible. The following may apply in one or more FM applications to maintain, assess the life cycle, spatial management and preparation, occupant satisfaction improvement, restoration, health and safety, condition assessment, and refurbishment are some of the services. FM is influenced by three major factors: the state of the economy, the configurations of buildings and services, and external disruptions (Pärn et al., 2017), so that their uses can differ, given that the elements change. As no one-size solution suits all, the stakeholders' involvement and participation are essential to achieve the importance of BIM in the process (Ilter & Ergen, 2015).

1.2.1 Challenges that Facility Managers Face

A facilities manager is always engaged with one or more operations and always assigns obligations and supervises the pace of work to assure the appropriate upkeep of the building. He can also be intertwined in the balance between security and economic efficiency for residents and owners. Yet, somehow, every request made by individuals does not come to the facilities provided and does not track or handle the problems effectively.

- **Cost Control**

Cost control, in a nutshell, is one of the most challenging tasks facing a facility manager. Every requirement that an installation manager needs to meet has a cost. Equipment such as employee recruitment, renovations, stock and logistics, security, and safety are not easy to get or affordable. The quality of the facility given must be balanced and made into the budget.

- Aging inventory

The management of aging inventories is another difficulty for a facility manager. As time goes by, the building's devices and other equipment tend to deteriorate and wear down. This inevitability causes leakages and breakups. In addition, a facility manager must follow proactive and preventative maintenance processes, which impact the quality of the installations delivered

- Regulatory and Compliance Requirements Altering

Adherence to ever-changing regulatory and compliance norms is another impediment to providing top-notch facilities for a property manager. In addition, a facility manager must cope with keeping up with leading industry trends and necessary enhancements.

- Safety and Security Management

Infringements of security and threats have dramatically raised the worry of a site manager about security obligations. This requires an operator to concentrate on the necessity of emergency preparedness. There is still a lot to do with emergency evacuation protocols in many companies. It is an arduous effort to bring the organization up to speed.

1.3 Objectives

In the age of the technological revolution, data retrieved from technical devices like sensors and numerical computation remain the cornerstone of any successful construction management case. Nonetheless, an unsuccessful integration between any BIM model with the accurate data that is supposed to be received will cripple the facility manager's ability to diagnose the underlying defects.

The purpose of the dissertation is to propose a framework and suggest integration between BIM and IoT goals: alignment, modeling, and diverse integration and Visualization as follow:

1. Automated alignment depends on the automatic physical data collection from in-space sensors by integrating the HVAC system with IoT sensors then store this data in the BIM model of the cloud.

2. Algorithmically visualizes the attribute using a color palette paradigm extracted from the BIM model.

The IoT and BIM integration is relatively a new field in the engineering industry. Thus, the development is undergoing a series of trials and errors and trying to reach the best-case scenario in implementing and developing this integration.

The world undergoes some significant changes that have a direct effect on everything, including the construction industry. In the last two years, the world has been mesmerized by COVID-19 and its consequences on all aspects. This research highlights the effect of COVID-19 on the IoT-BIM integration in the operation phases.

These findings were then used to conceptualize a BIM-enabled FM framework grounded by innovation and determining future research paths.

1.4 Research Questions

Although there is gathering evidence of the economic and environmental benefits of sustainable practices in existing and new buildings, there is still a perception of the high cost to achieve high performance or “green” in Facility Management. That concern is indeed justifiable, and the construction industry can be forgiven if it struggles to bring sustainable development on board since there is a shortage of sound guidance on what the concept means [for Facility Management] in the long-term and what the industry would have to do to achieve it.” Within this context, the focus of this research is divided into three main research questions.

1. What are the links between BIM and Facility Management in existing buildings?
What are the links between FM and sustainable building operations?
2. How can BIM frameworks be integrated and implemented to reduce operational GHG emissions through facility management?
3. What are the future policies and procedures for FM development?

1.5 Research Qualitative Methodology

An extensive literature review has been done to cover the assessment on integrating BIM and IoT devices since before 2012. Publications tackling BIM and IoT integration were uncommon. Ultimately, after 2012, publications tackling BIM and IoT integration have witnessed a remarkable increase (Chang et al., 2018, p. 1086). In this manner, AEC journals have been utilized via the Web of Science database and Journal Citation Report. Besides, clarifying probable future BIM frameworks for sustainable facility management processes and best practices is a cornerstone in assessing the contemporary building designs' status quo and predicting BIM and FM's sustainability. Thus, examining BIM, FM, and sustainability in the universal context is of crucial importance.

Moreover, for more accurate conclusions in case studies on the current building plans, the databases of the Association of Computing Machinery (ACM) and Institute of Electrical and Electronics Engineers (IEEE) Xplore were scanned. In this manner, the keywords used were "Building Management System (BMS)," "Internet of Things," "IoT," "Smart City," "Smart Building," "Building information modeling," "BIM," and "Sensor."

A qualitative approach to sustainable facility management will be adopted in this research. Coyle (2000), qualitative research approaches have five overarching objectives: simplify a complex issue, facilitate debate by highlighting the relationship between the subjects discussed, help clarify behavior and generate insight, aid in identifying a broader context of a subject and, when considered essential, provide the foundation for further quantitative research. The issues of BIM, FM, and sustainability will be discussed primarily in the global context of buildings. In thoroughly investigating the research problem, the research will draw upon multiple research methods to critically assess the status quo, seeks to provide greater understanding and applicability of BIM's faces and concepts in the modern construction of buildings – via case study and techniques for the survey to highlight excellent practices and discover possibilities for the future. The qualitative research methodologies used for this research are summarized in figure 1, while the following sections clarify each approach further.

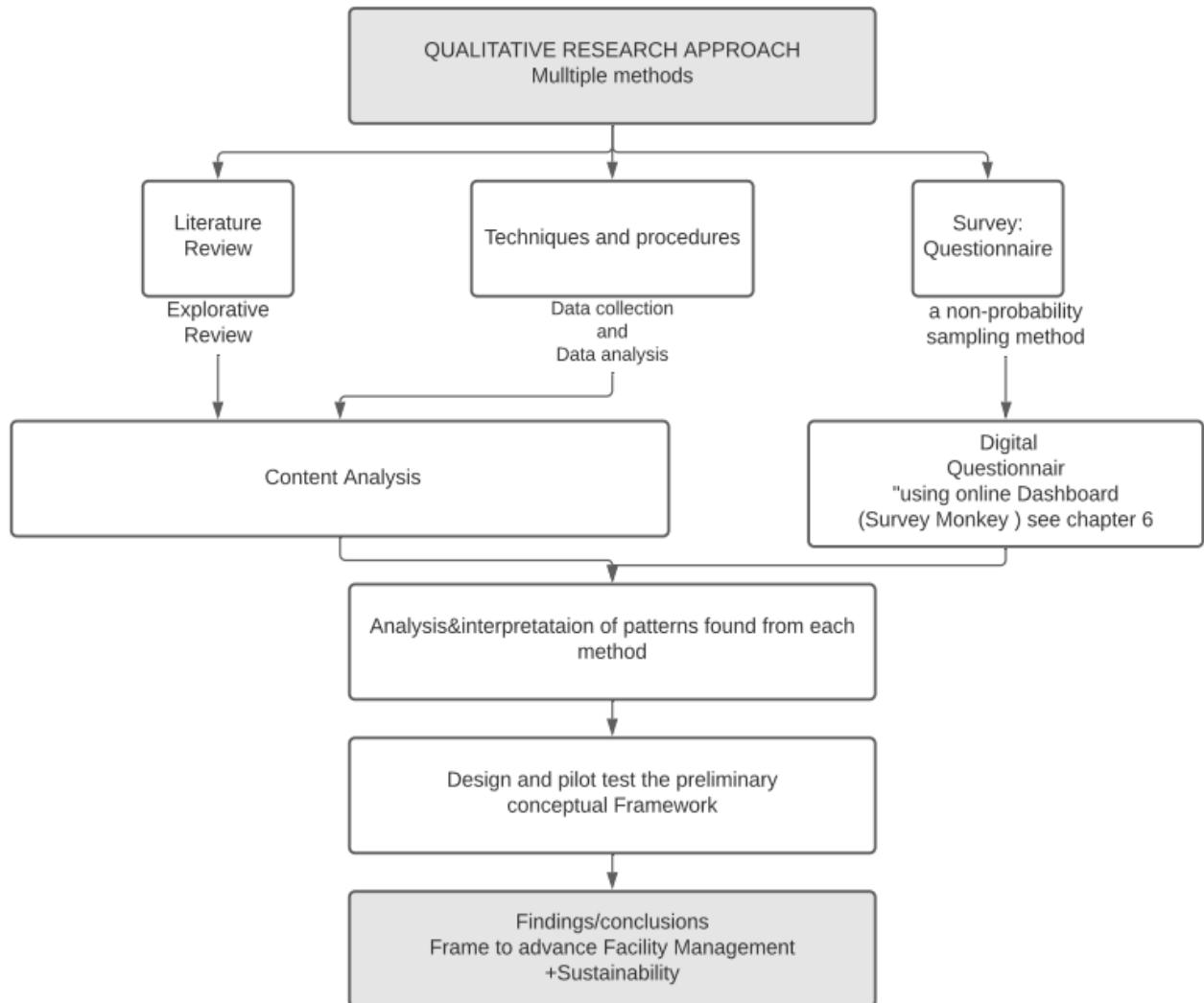


Figure 1: Qualitative research methods and process

The study proposal of combining facilities management with BIM and IoT guarantees the building's long-term sustainability efficiency. The operating stage of the building is estimated to be the costliest time in the building's life cycle. Reducing both environmental along with expense debt by informed decision-making is essential. Therefore, this study examines the principles that are considered and the mechanisms currently taking place as BIM integrates with IoT.

BIM depicts a structure as a directory of synchronized information coherent and calculable in design and facilities management. Working throughout BIM entails collaboration and interaction across a single shared network to involve all project stakeholders. When architects, engineers, and designers incorporate, the need for more efficient construction management grows, and this is when BIM's effectiveness takes part. The

cost of insufficient data computing in the FM industry amounted to the US \$ 15.8 billion, according to the 2002 study by the US National Institute of Standards and Technologies (Liu & Issa, 2016).

The study states that the owners of the facilities cover over 65% of this expense. Ironically, almost 85 percent of this budget, or about US\$ 9 billion, would be incurred during the facility's repair and maintenance stages (Liu & Issa, 2016).

1.6 Scope of Research

This research pinpoints some specific targets. The study aims to develop and enhance the sustainable Facility Management process via the BIM-IoT integration used and draw a guideline and an outline for the FM personnel to apply the best practices in FM via the BIM-IoT integration. The research focused on the BIM-IoT integration qualitative approach, methods, and best practices while disregarding the mechanism or the technique of achieving this integration. Neither did the research focus on the know-how of the BIM-IoT integration in FM in terms of quantitative approach. On the other hand, the research aims to explore and broaden the value of BIM-IoT integration using different tools and gadgets, such as HVAC sensors used by facility managers and personnel. The framework and scope of research draw an outline for the personnel without giving much detail on the technical process itself, such as cloud storage, machine learning, or IoT architecture.

2. Fundamentals Concepts

2.1 Fundamental Concepts of Facility Management

2.1.1 Facility Management (FM): Definition and Concept

Brian Atkin and Adrian Brook's (2009) interpretation of FM is a unified approach to promote a supportive environment for an organization's primary objective via operating, maintaining, and adapting buildings with infrastructure. Furthermore, the International Facility Management Association (IFMA) defines FM as a specialist who manages to build output by combining staff, location, operation, and technology to ensure the quality of the building's setting (IFMA, n.d.). These definitions and interpretations seek to ensure the optimum interaction, integration, and precision between the intellect and technology, as shown in figure 2 (Sindhu & Gidado, 2014).



Figure 2: FM Functions Reprinted from (IFMA, n.d.)

Table 1: Difference between Hard and Soft FM Categories. Reprinted from (Arayici et al., 2012) .

	Soft Facility Management	Hard Facility Management
Definition	Sustaining of environmental aspect in a building in all operations	Maintenance of activities that must be done on a building's premises
Aim	Users' comfort while using the building	All functions run flawlessly 24/7 in a building
Examples	Space Management, Internal plants, Catering, Security, Cleaning, Ground Maintenance, Water disposal, Recycling, etc.	Mechanical and Engineering, Heating, Ventilation, Air Conditioning (HVAC), Drainage, plumbing, elevators, escalators, etc.

2.1.2 Building Performance & Facility Management Relationship

Like all things, buildings will face a near collapse or inhumane living context if they do not require maintenance. There is a direct linear relationship between building performance and FM. Figure 3 illustrates this linear relationship. The more efficient and continuous FM, the more it affects the building's operations, notably external and internal factors like weather conditions and defective maintenance (Douglas, 1996, p. 24). In this manner, buildings' maintenance and FM must be advised and included in the early design stage to maintain efficiency.

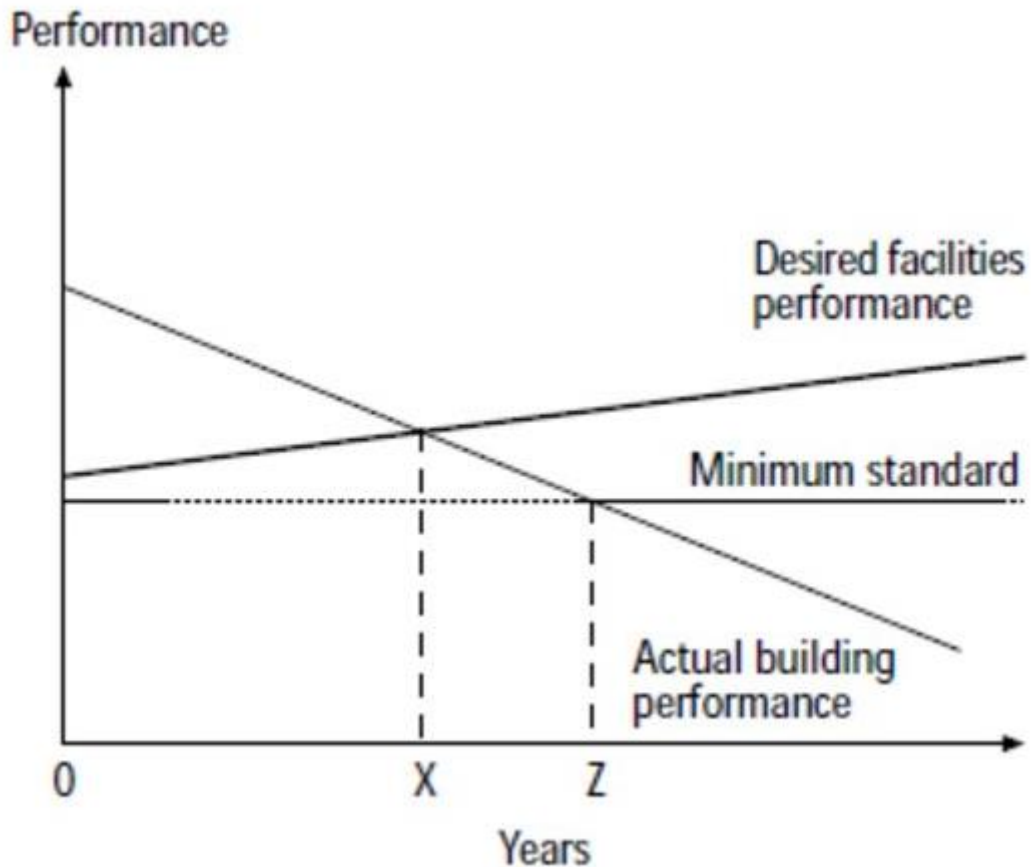


Figure 3: The Relationship between Building Performance and Facilities Performance. Reprinted from (Douglas, 1996, p. 24)

2.2 Fundamental Concepts of Building Information Modeling (BIM)

2.2.1 Definition and Concept

BIM is an intelligent 3D model-based method providing information and tools to Architecture, Engineering, and Construction (AEC) practitioners to design, build and manage buildings and infrastructure more effectively (Abbondati et al., 2020). As an acronym, BIM has evolved from the building information model to building information modeling/management. It was first used to highlight the data object. Afterward, it kept evolving as it stressed the human input in the process (Eastman et al., 2011). For a more effective result, BIM included altering organizations and their practices using BIM in all construction and post-constructing phases. In this manner, BIM has shaped the

industry's stakeholders in every phase and step throughout the life cycle (Becerik-Gerber & Kensek, 2012, p. 146). For BIM, architectures and designs of infrastructure are designed and documented. All architectural details are BIM modeled. The model may be used to explore design choices and visualize to allow stakeholders to see the appearance of the building before it is completed (Eastman et al., 2011).

Nevertheless, BIM can be a valuable new method for facilities management to improve building efficiency and more effectively control activities over the lifetime of a building. It should be noted that the current use of BIM is a novel method to using BIM, which requires more testing (Underwood & Isikdag, 2010).

Another definition presented in Underwood and Isikdag (2010) defines the building information model includes relevant and comprehensive data to sustain life cycle processes that can be translated directly by programming applications. It contains data on the building as well as its dependencies and includes detail on properties, including purpose, type, component, and procedures for the construction period.

Deutsch (2011) described BIM as a method, in contrast to software, technologies, or tools used to generate and manage building data over an entire lifespan, from conceptual planning to construction installation and repair.

2.2.2 BIM History –BIM origin

Professor Charles Eastman of the Georgia Tech School of Architecture pioneered BIM in the late 1970s. Since the inception of BIM, many perspectives have expanded, including architecture, cost analysis, construction phase, construction lifespan, and technologies. The aim of integrating BIM in building projects differs based on the level of the project: pre-construction, construction, and post-construction. BIM was first used effectively by the AEC in the mid-2000s. The Building Description System (BDS) was the first program to provide a separate inventory of building components that could be downloaded and applied to the proposed system. The concept is modeled by Charles Eastman in late 1970, who believed that the actual result was unsatisfactory due to several problems, including inadequate building sketches that illustrated the same image at various sizes and drawings that were not revised under the project's final status (Latiffi et al., 2014).

By the late seventies, Eastman argued that architectural sketches were ineffective because they restricted themselves to the visualization of the structures and did not upgrade their drawings. As a result, numerous institutions in the United States and Finland created computer systems that used ICT to solve those problems. The evolution of the BIM concept based on computer programs between 1975 and 2010 is shown in Figure 4.

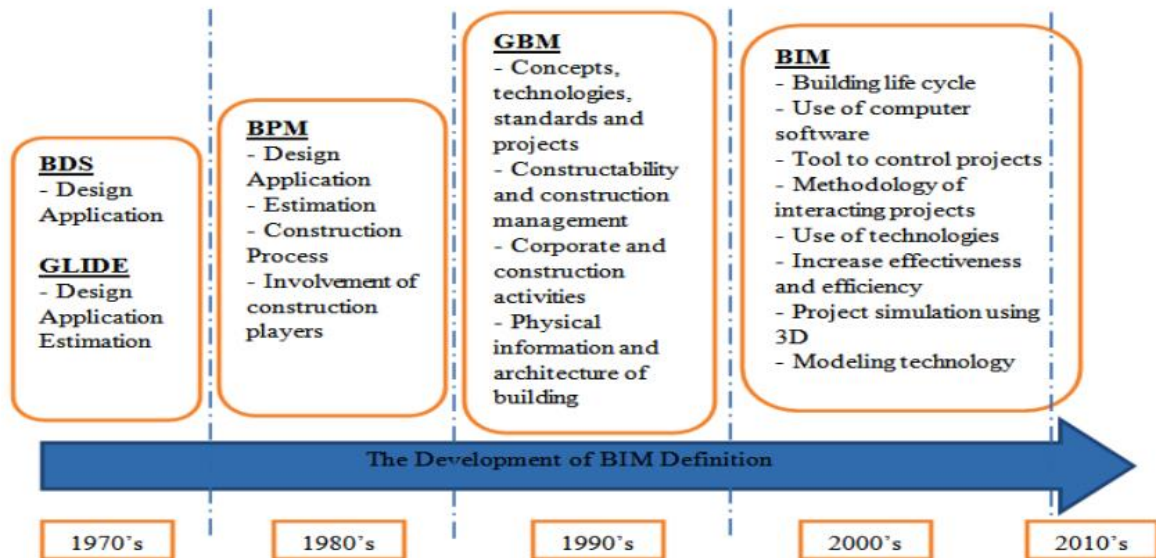


Figure 4: The Development of BIM Definition Reprinted from (Latiffi et al., 2014).

In 1975, Professor Eastman implemented BDS, which facilitated collaboration in the production of architecture. BDS is known as a database that allows the design and construction of buildings. BDS has been used to create a model of highly complex systems consisting of item configuration. A wide variety of features and design collision exposure must be described, modified, and arranged by the BDS. BDS runs from the collection of different library components. It illustrates how the BIM description has been established based on Figure 4.

Moreover, BDS improves the representation of custom-built applications and construction systems. The emphasis is paid to the characteristics that differ from specific building description systems, data structures, the system of access, and the interacting process between the database and the testing programs. Through drafting and analyzing performance BDS could reduce design costs. The advantages of BDS include the

ability to identify, alter, and organize a wide variety of components and diagnose layout inconsistencies. BDS runs from the collection of different database components.

Moreover, BDS improves the representation of specially built applications and construction models. The emphasis is paid to the characteristics that differ from specific building description systems, data formats, accessibility, and the interacting process between the database and the testing programs. Through drafting and analyzing performance BDS could reduce design costs (Latiffi et al., 2014).

2.2.3 BIM Maturity Levels

BIM Alliance Sweden started as an initiative that began with 180 companies. It is a non-profit organization that merged three unions: OpenBIM, building SMART Sweden, and Facility management information. Its purpose is to promote joint mechanisms and tools for BIM implementations, management, and development. (About BIM Alliance, 2017). According to BIM-alliance, there are four levels of BIM-maturation evolution. Level 0 starts with CAD drawings and their usage as the main analog document of buildings with 95% uncoordinated users' drawings. Level 1 comes later when 2D and 3D computer file models regard object information and other systems operations. In this manner, file management is detached and not combined with the facility management system. Level 2 is an upgrade where the system utilizes information for object-based models while having interoperability. Level 3 uses standardized information models in building lifecycle and support systems in organizations' practices for covering future scenarios. Information flow is ensured by open databases and web applications with a possible profit of 2% in a more secure collaborative process (Dakhil et al., 2015, pp. 1–3).

On the other hand, the U.S. Army Corps of Engineering initiated COBie in 2006 to fix the interoperability issues regulating FM-specific data provision (U.S. Army Engineer Research and Development Center & William East, 2007). COBie tailors the delivered information per project rather than providing a neutral data format or geometry-based building models as IFC does (U.S. Army Engineer Research and Development Center & William East, 2007; Tarandi, 2012).

2.3 Fundamental Concepts of Internet of Things (IoT)

2.3.1 Definition and Concept

In a nutshell, the Internet of Things (IoT) is when tangible objects facilitate our lives and day-to-day activities using information systems. IoT has led to a radical evolution in the world as we used to know. One of the milestones in human history is the 24/7 availability of the internet worldwide with sensors to embed objects to systems facilitating the connection between people and networks of devices. (Atzori et al., 2010). In Computer Networks, the Internet of Things survey conducted by Atzori et al., 2010 reached the three concepts: internet-oriented (middleware), thing-oriented (detectors), and semantic-oriented (knowledge).

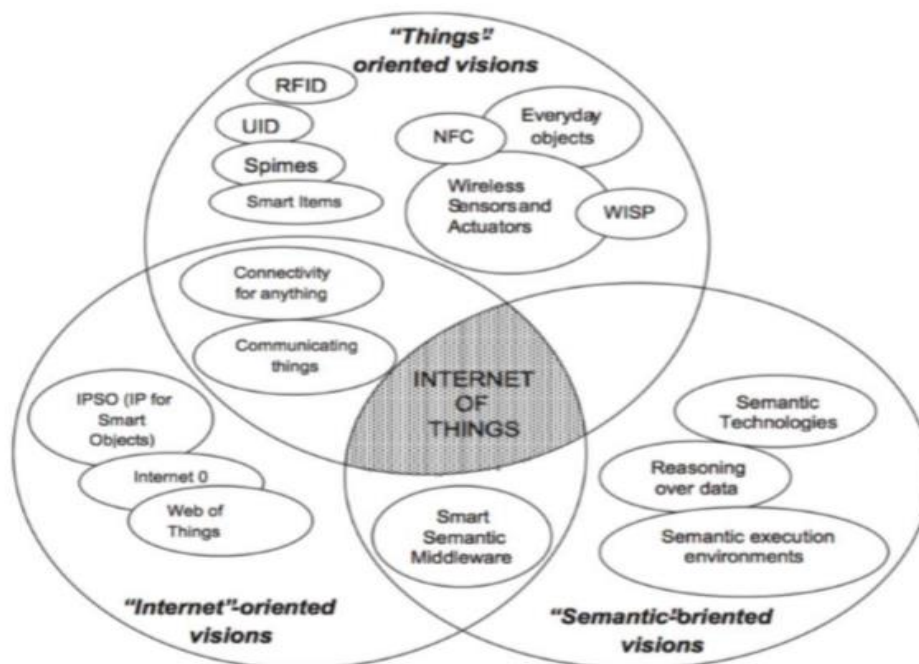


Figure 6: Internet of Things. Reprinted from (Atzori et al., 2010)

2.3.2 Sensor networks

Since the latest Internet of Things is based on various architectural models, a practical network requires six fundamental elements, as shown in figure 7.



Figure 7: IoT Elements. Reprinted from (Schmidt, 2016).

The targeted sensors in IoT are devices that measure various physical world parameters like pressure, temperature, humidity, carbon dioxide, movement, water, gas, and electricity meter readings (Gökçe et al., 2009). sensors that depend on wired connections like USB cables are usually not as responsive as sensors with wireless connections in sensor placing positions. In this manner, the Wireless Sensor Network (WSN) was created to maximize cost-efficiency and flexibility compared to wired installations (Malatras et al., 2008, p. 509). WSN paved the way for linking the physical world with the digital one via many tiny sensors connected wirelessly (Malatras et al., 2008, p. 509). After expanding BIM usage throughout buildings' lifecycle, the prominent future of WSN can be detected.

2.4 Most Used BIM and IoT Integration Domains

A BIM-based system supports secure servicing and maintenance during the facility management period via safety identification/classification features, data analysis and directive decision making, and user interfacing.

Facility Management (FM) staff play a critical role in developing, maintaining, and administering these complex structures (Liu et al., 2012). FM employees, as specialized experts, draw on knowledge from a wide range of fields, including mechanical, electrical, plumbing, and fire protection (MEPFP), to assure the building environment's reliability (IFMA, n.d.). The credentials for FM professionals and the skill fields required for facility management are frequently determined by the functionality of the processes.

2.4.1 FM Relevant Safety Details

The more time and effort an individual must spend on collecting information, the less possible the information will be obtained, and alerts will be complied with. The possibility of implementing the protection protocol has now become far stronger (Wetzel & Thabet, 2015) by minimizing work and effort to achieve the lowest possible degree of information recovery. In an area where assignments sometimes are time-sensitive, it is indispensable. The burden of too many task orders and short periods leads to haste, which has proven itself to be directly linked to job accidents and mortality rates (Wetzel & Thabet, 2015).

2.4.2 Safety Data Details

There is a range of sources of information applicable to the secure management of an installation. Contract agencies often present this knowledge via a series of contract-required documents during the building's lifecycle, as shown in figure 8. Plan drawings, specifications, and 3D models, which are often created during the design process, include power sources, reconnect positions, elevations, Etc. Once architects and engineers (A&E) start designing a structure, routing control, disconnection proximity, number of valves, equipment components' elevation, and many other factors influence maintenance requirements during the FM process. Knowledge of this causality, as well as the architecture to sustain downstream lifecycle stages, is referred to as the Prevention through Design (PtD) or Safety for Design (DfS) (Gambatese et al., 2008; History and Future of PtD, 2017). The application of PtD/DfS is a powerful method for improving accident reduction; However, traditionally, the scope of attention was mainly on the building process and, more minor, on the FM phase.

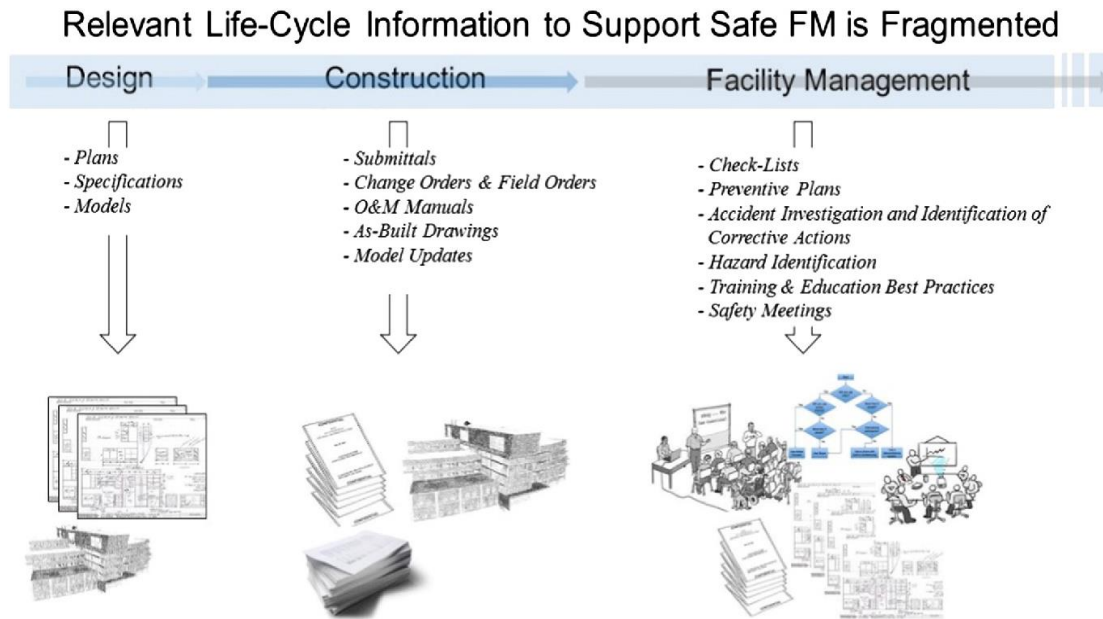


Figure 8: Safety Documentation Sources during the Facility Lifecycle. Reprinted from (Wetzel & Thabet, 2015).

FM staff has recently been interested in projects during the design and construction phases to assist in this form of decision-making within the scope of BIM-FM. Particular equipment configurations or associations with suppliers/contractors are often used to reach the best decision. Concerning project-specific information, FM personnel may receive safety information from corporate frameworks and regulations. Internal standards for facility management play an essential role in implementing safety policy through safety workshops, checklists, handbooks, guides, and legal precedent. The owner/facility manager is solely responsible for the healthy maintenance of the facility as the Supervisor of facility management employees. Failure to adequately train employees or ensure a healthy working atmosphere can result in worker's compensation lawsuits and prosecution (Wetzel & Thabet, 2015).

2.4.3 Security & Safety details fragmentation to help administration of facilities

In facilities management, safety-related data is incorporated into various resources generated throughout the project's life cycle, resulting in inefficiencies in information acquisition. When a piece of hardware needs servicing or replacement, any safety issues applicable to the maintenance phase of that equipment must be addressed by

the FM staff. To achieve an extensive understanding of the mission, references would probably be extracted from many reports (Wetzel & Thabet, 2015).

The disadvantages that complete safety information can be dispersed over many databases and the sensitivity of FM activities frequently present can cause FM staff to bypass the collection of applicable information and exacerbate the probability of work-related accidents. Recently a significant step has been made for operating and maintenance information to be incorporated into BIM models and CMMS to simplify information and increase information collection performance. The boost in O&M Storage and Recovery was accomplished by applying BIM interoperability, virtual databases, and add-ons like COBie (Wetzel & Thabet, 2015).

The ease of accessing and receiving a robust security protocol for the MCC is significantly enhanced by defining and consolidating the security details applicable to the FM mission. While some of this information could be maintained in a virtual database or 3D model, extensive job-specific safety information is unattainable. Reducing the FM worker's discomfort and creating a unique contact point will increase the chances of implementing the guide and protection protocol.

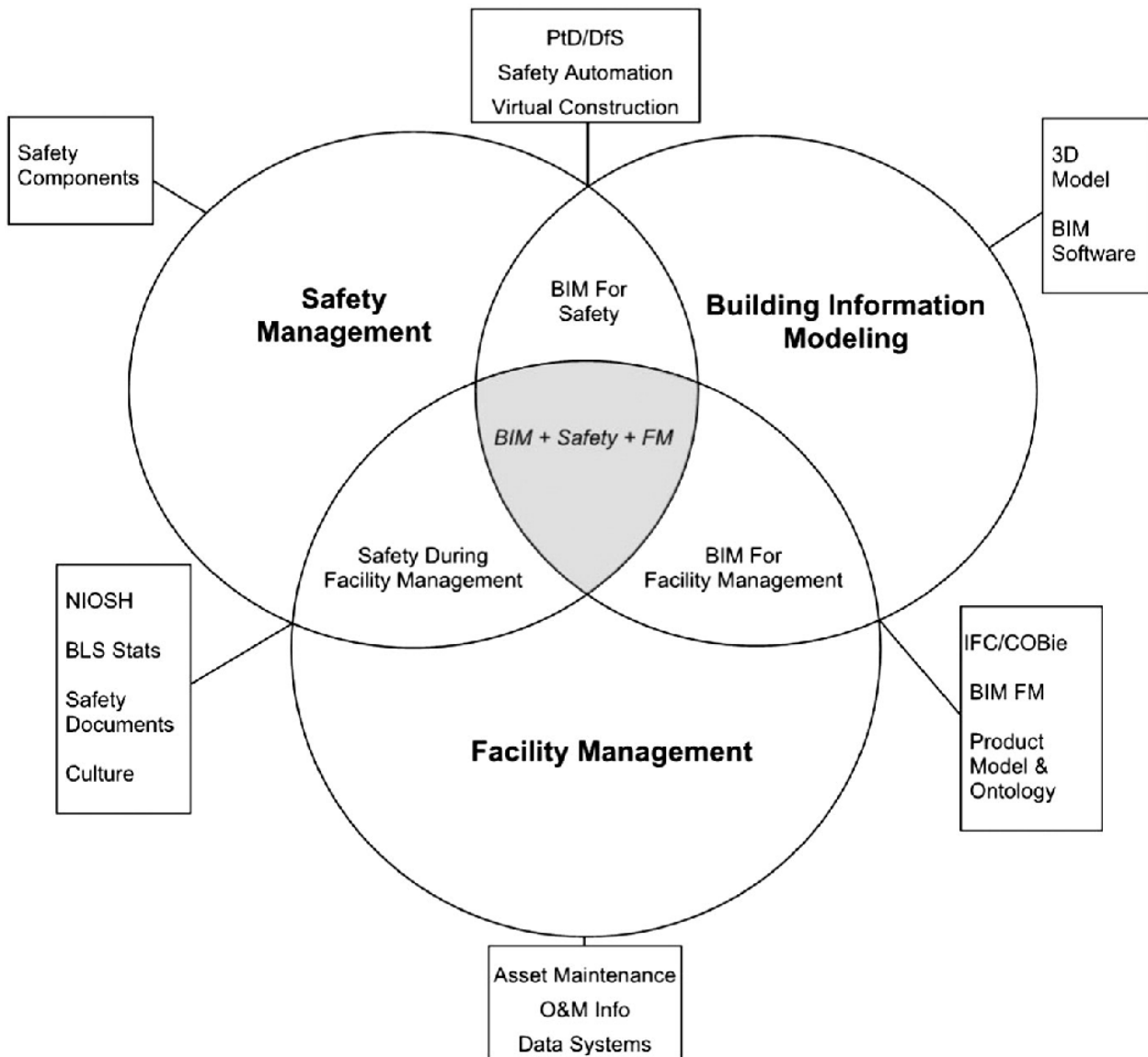


Figure 9: Venn Diagram for Literature Review. Reprinted from (Wetzel & Thabet, 2015).

The National Building Information Model Standard (NBIMS) accepted an aspect of the Construction Building Information Sharing (COBie) Standard in December 2005. COBie was designed to improve how information is collected and then passed to the operating and maintenance owners during the planning and building phase. COBie leverages IFC's open data format to map the similarity across the architectural, development, and FM phase to bridge the gap. Using an open-source, interoperable collection of generic characteristics, users can customize the data to fit their facility requirements (Wetzel & Thabet, 2015).

Aside from data migration, a facilities management data system may assist FM divisions in managing and monitoring equipment, issuing task orders, and carrying out

various other FM tasks. Controlling and operating facilities work on several technologies, from manual and tablet to more modern computer-based programs like CMMS, computer-assisted facility control tools (Wetzel & Thabet, 2015).

2.5 Concluding Thoughts

Sustainable facilities management is the collection of actions related to facility investment, operation, and maintenance that improve the sustainability of facilities within the decision maker's locus of control. In this situation, making more sustainable judgments necessitates considering both the short- and long-term effects of viable options on facility stakeholders such as landlords, developers, users, administrators, investors, renters, and others. Building users' needs in support of their organization's goal must be recognized first and foremost. Healthy buildings that promote occupant safety, well-being, and more sustainable operation are part of the company's goals and mission.

BIM and IoT integration aim to care about the environment and, more importantly, minimizing the cost and time waste of the building during all phases from design to operation and demolition. In this manner, synchronizing BIM with FM allows the best practice of such integration as soft and hard FM is facilitates building management in most aspects.

3. The link between Building Information Modelling and Facility Management

For a successful FM and BIM integration, BIM needs to maintain the navigation capabilities' distinct feature; it directs FM employees to the malfunction, just like a GPS (Global Positioning System) with maps. By supplying digital devices to FM staff, their reliance on office personnel and paper-based systems will decrease. Moreover, BIM models and FM databases integration enable a more effortless and quicker diagnosis of building equipment concerning the maintenance history and specifications, which can be connected automatically with the located equipment and delivered on-site (Becerik-Gerber et al., 2012, p. 438).

3.1 Promoting Real-Time Access Control

FM personnel oversee every aspect of maintenance and repair in a preventive, predictive, and corrective manner. FM personnel respond to any trouble in the built environment, turning the heat high or low, for example. Further, FM personnel administer replacing outmoded items and handling predictive tests and inspections to maintain the built environment. For the FM personnel to successfully execute these tasks, they need open access to multiple databases with vast information. In two separate FM foundations (i.e., diagnostics a faulty object and an issue with area airflow), the data and experience acquired during maintenance and facilities operation can lead to more input and best-case scenario solutions in the management database transfers to the BIM model. In this manner, the probability of making an ineffective decision decreases because of the practical and instant data access (Ergen et al., 2007, p. 358).

Accordingly, BIM's graphical interface grants data connectivity to necessary data that has been unified. FM employees can access information about the target malfunction and analyze the required FM device data. Nevertheless, this integration cannot reach success if interoperability between solutions is undefined or neglected. Table 3 demonstrates a feasible BIM-based digital data interface (Becerik-Gerber et al., 2012, p. 435).

Table 2: Conditions Illustrating the Information Requirements of the FM Personnel. Reprinted from (Becerik-Gerber et al., 2012, p. 435).

FM information systems	Computerized Maintenance Management System (CMMS)	Electronic Document Management System (EDMS)	Building Automation System (BAS)
Appliance malfunction troubleshooting	<ul style="list-style-type: none"> - Initiate a work order for the equipment, - Check the appliance's history. - Information assessment 	<ul style="list-style-type: none"> -Operation and maintenance manuals, warranty: Operation and maintenance documents - Initial reports. -Performance assessment. -Design schedule information; 5D Technology - 3D view for primary parts and distribution 	<ul style="list-style-type: none"> Appliance's coverage area. - Sensor information, set-points verification. - Design Vs. actual data Vs. start-up report. - Reference points for benchmark verification. - Network analysis on a distribution system. - Diverse troubleshooting locations
Room temperature imbalance/	<ul style="list-style-type: none"> - Initiate a work order for the room, zone, floor, building, Etc. - Work order history for urgent and troubleshooting calls 	<ul style="list-style-type: none"> -Location of the variable air volume (VAV) box of that zone. (VAV unit, or outlet box) - Thermostat position 	<ul style="list-style-type: none"> - Room sensor and room to zone logistics - VAV and AHU reading/controls switch back and forth

3.2 Visualization and Feasibility Studies

The visualization and logistics strategy has been highlighted and deliberated in various building projects (Becerik-Gerber et al., 2012, p., 435). The 3D graphic interface with the AI of integrating different surroundings, including material texture, light sources, Etc., allows BIM to implement a visualized layout to facilities managers in the development and engineering of renovation and restorations.

The 3D layout can be applied as teaching content to train the residents on exit strategies in case of emergencies. In the same token, this three-dimensional graphic model offers a marketing feature for developing images and animations for the interior design through navigating, walkthrough, rendering, and virtual 3D strategies accompanied by BIM technology. (Becerik-Gerber et al., 2012, p., 435).

According to both work and resource feasibility scales, part of the FM organization's responsibility is to remodel, renovate, or demolish existing buildings. Meanwhile, BIM collaborates in designing, analyzing, planning, and simulating models. BIM allows detailed insight into the interior and exterior aspects. In addition, BIM rescales the dimensions of large-scale items and predicts the appropriate building materials. Moreover, cost estimations and decision-making can be much easier as references for the planned work and databases are linked and accessible. Previous embedded data like material, labor, or cost of designing and construction can be extracted easily. In this manner, a 4D (four-Dimensional) analysis can be conducted as a simulation for the construction and operational phase. With BIM application in the facility's different stages, it is more feasible for the FM personnel to utilize the design, estimate the cost, and put BIM into action. (Becerik-Gerber et al., 2012, p., 437).

3.2.1 Emergency Management and Energy controlling

BIM can be the first quest for emergencies to locate, diagnose, and pinpoint potential troubles and hazards via the graphical interface it updates. Another vital usage of BIM's spatial information is labeling latent information and relationships between evacuation routes and environmental risks, thus increasing decision-making security. (Zhichong & Yaowu, 2009, p., 354). In the scenario of potential emergencies, decisions and priorities must be decisive and alleviated. BIM can contribute with specific detailed information and procedures before the emergency units arrive. BIM acts as a first responder to pave the way for the best-case scenario with the least cost. For instance, in case of fire in a commercial building, BIM pinpoints the nearest extinguishers and discharge pipes, and floor blueprints, electrical panels, as well as emergency exit paths. In another probable crisis, an earthquake, BIM can save time and effort by classifying facilities that may be equipped as evacuation shelters, first aid supplies, Etc. In this manner, BIM does not merely provide FM personnel with better training and best-case scenario schemes. It can also be used as a simulation tool for potential emergencies and better evaluation and assessment for damage and response plans. (Becerik-Gerber et al., 2012, p., 437).

Energy management systems are one of the pillars that FM personnel depend on in measuring energy usage in a facility or zone-level in both predicted and actual periods.

Adding new building floor plans is one of the core malfunctions in these systems, especially when supervising and controlling equipment graphics or managing and updating graphical information like diffusers, terminal boxes, thermostats, ducting, Etc. In this manner, time is diverted from floor plans to energy management system graphics (Becerik-Gerber et al., 2012, p. 437).

3.3 Facility Management and Data Information

3.3.1 Facility Management Domains and Occupants perspectives

The employment of BIM in the service of FM has been the subject of research for several years. Facilities managers will have integrated methodologies for building operation and maintenance, building efficiency monitoring, energy management, and disaster and emergency response plans after deploying BIM and IoT technologies (Srinivasan et al., 2012).

Concerning the data layer, in the case of Tyréns and the conceptualized context of Gökçe and Gökçe analysis (2013), there are two sources known as sensor data and BIM data. The building occupancy information is another data source cited as an energy data repository source written by Wang et al. (2013), but this source has not been interpreted in plain terms. From the standpoint of occupants, the occupants' data can be deemed critical as BIMs and sensors. However, to be more transparent, this supplementary data source is required. Occupant data consists of three types of information that refer to the three circumstances of what the occupants act, perceive, and comprehend (Nguyen, 2016).

- **Function:** Each occupant has a different work style with such tasks concerning the occupant's working patterns in terms of the workspace. The office position at which people spend most of their time at work is also essential (Nguyen, 2016).
- **Interpret:** The occupants have their own spatial and psychological comfort zone, which profoundly affects building performance satisfaction (Nguyen, 2016).

- Acknowledge: After a while, occupants will be given information about how they saw the building as appropriate and insufficient. The opinions evolve and change (Nguyen, 2016).

3.3.2 Maintenance and Building Operation

BIM with IoT integration provides the proper channels for activities, including real-time data access and maintenance inspections, building digital assets, and managing space (Becerik-Gerber et al., 2012). Defining physical building components and linking them to BIM models using RFID tags for asset tracking (Chen et al., 2015; Shen et al., 2012); linking physical objects with digital objects using BIM tool APIs for O&M extracting real-time data and visualizing problems using Augmented Reality (AR) devices (Pärn et al., 2017).

Publications in BIM-based modeling, evaluation, optimization and management of construction results have increased at an exponential rate in recent years (Gerrish et al., 2017). Other applications can become interoperable, transparent, automated, and integrated with the help of BIM. As a result, the scope for BIM integrating with IoT devices can be definitive to the timely reading of BIM temperature and humidity information from BIM tools (Marzouk & Abdelaty, 2014) as well as optimizing operational comfort (Shen et al., 2012), which connects BIM with BIM's real-time building data. In addition to monitoring the quality of the indoor environment (IEQ). Furthermore, context data was changed to the web standard for either BIM models or the file Industry Foundation Class to track and measure the efficiency of buildings with real-time online technology (Corry et al., 2014). (IFC). These studies will modify cross-domain knowledge and real-time web-based sensor readings to meet the needs of cloud-based software and facilities such as energy control, building efficiency monitoring, and building maintenance (Curry et al., 2013).

3.4 The Concept of Sustainable Facility Management

According to Baharum and Pitt (2009), if FM practices are acknowledged as a critical component of improving company competitiveness, they must be sustainable. Sustainability was listed as one of the main challenges confronting FM practitioners today in

the 2007 IFMA study indicated that evaluating the emerging trends and potential prospects for facility management professionals, as recognizing the management of facilities that embrace sustainable practices as one of the main challenges confronting FM practitioners today (Baaki et al., 2016).

Sustainable FM is concerned with being prepared to handle, implement, and execute non-core business services of an organization which help enhance the financial, physical, and social environment, and in turn to improve environmental sustainability in line with the core business vision of a company per Cotgrave & Riley (2012, p. 242).

FM is now widely acknowledged as an integrated function that runs, operates, and develops companies' facilities and infrastructure to function effectively, allowing core business to thrive. Furthermore, FM has a distinct identity as the backbone of corporate backing. It is enough to mention that the sustainable FM idea is best characterized in terms of economic profits, the environment, and the social consciousness of a business (Pitt et al., 2009, p. 201).

Legislation, intense market competition, and rapidly changing corporate environments all necessitate the pursuit of competitive advantage. Surprisingly, influence from stakeholders, personnel, and lifecycle cost reduction was ranked as the least important drivers of SFM implementation. One might argue that organizations appear to be driven more by external forces than internal elements (I. Ikediashi et al., 2014, pp. 302–322).

While the corporate image was regarded as a primary essential determinant to SFM, employment creation for local communities, environmental sustainability, and strengthening connections with stakeholders were highlighted as the main drivers to SFM. The least driving elements of SFM were identified as pressure from top management, pressure from clients, a decrease in deforestation, and government regulation. These findings reveal a superiority of environmental sustainability, with aspects of social sustainability and no clear leading causes of impoverishment.

Table 3: Sustainable Facility Management Drivers. Reprinted from (Baaki et al., 2016).

Classification	Drivers
Environmental	Waste minimization Productivity growth. Oil and air pollution elimination Sustainable urbanization Deforestation reduction CO ₂ emissions reduction
Social	Improve stakeholder rapport Local community job creation Government Regulations Corporate image Clients' demands Senior management's pressure
Economic	Profitability Investing incentive Life cycle cost-cutting Competitiveness Market share growth

3.5 BIM-Enabled FM Data and Process Requirements

The sections above illustrate the milestones that can be achieved in FM. Nonetheless, each data-intensive application aspect requires a whole process and personnel data qualifications. For BIM to enable FM practices, The challenge is to interpret these information criteria and determine who and where the data can be turned over during the project. Geometric data criteria for BIM and FM integration have dominated most

debates so far. The requirements for detailed, exact as-built versions of all building elements will differ, whether structural, architectural, mechanical, or site-plan safety accesses. Another condition is the accuracy of as-built models for central utility lies to the facility, in conjunction with the precision of telecommunication representations like proper establishment and annotation of outlets. FM guidelines concerning labeling, annotating, and coloring spaces for space type and usage are necessary.

Moreover, a coherent object tree organization hierarchy is a must for built-in schedules and operates the model's components. Besides mechanical, electrical, and plumbing (MEP) equipment, detailed clearance requirements are listed for sustainability and maintainability. For a more precise and successful integration, the focal point must not be the geometric data requirements, but the non-geometric data requirements should be considered (Becerik-Gerber et al., 2012).

Figure 10 demonstrates the data structure of non-geometric requirements in the facility development and lifecycle. The volume of data grows the way down the pyramid. The information is collected and analyzed by the workflow in various stages of facility building. At the top of the pyramid, service zone details for each unit, such as the location, building, level, room, and zone, are set and inputted into the BIM as a start. Two stages of naming are followed. first, the guideline of the pre-approved manufacturer and organization's numbering schemes are followed by the moniker and numbering of the FM system with BIM (Becerik-Gerber et al., 2012, p. 438). The terminology and numbers typical of manufacturers and company numbering schemes are standard naming conventions. To connect equipment with systems FM, BIM should also specify the vocabulary of components and unique serial numbers. Data relating to category and type of components can also be defined per industry guidelines (e.g., unformat, master format, or Omni class) or organizational standards of an FM organization. Data transfer can be facilitated for related component cases by classifying devices, materials, and finishes into classes and forms. The following details should be listed and allocated to BIM components for manufacturers and vendors, i.e., type, serial number, acquisitive source and date, the vendor's warranty, expiration, and use. Item characteristics and attributes should be added in the BIM when deciding the service region, category, model, and manufacturer/vendor details. A broad array of activities

from implementation to service or maintenance may relate to specification and attribute information. Some specimen data examples include type, importance, and description. Weight, capacity, energy consumption, and spare parts are a few of the technological characteristics of components (Becerik-Gerber et al., 2012).

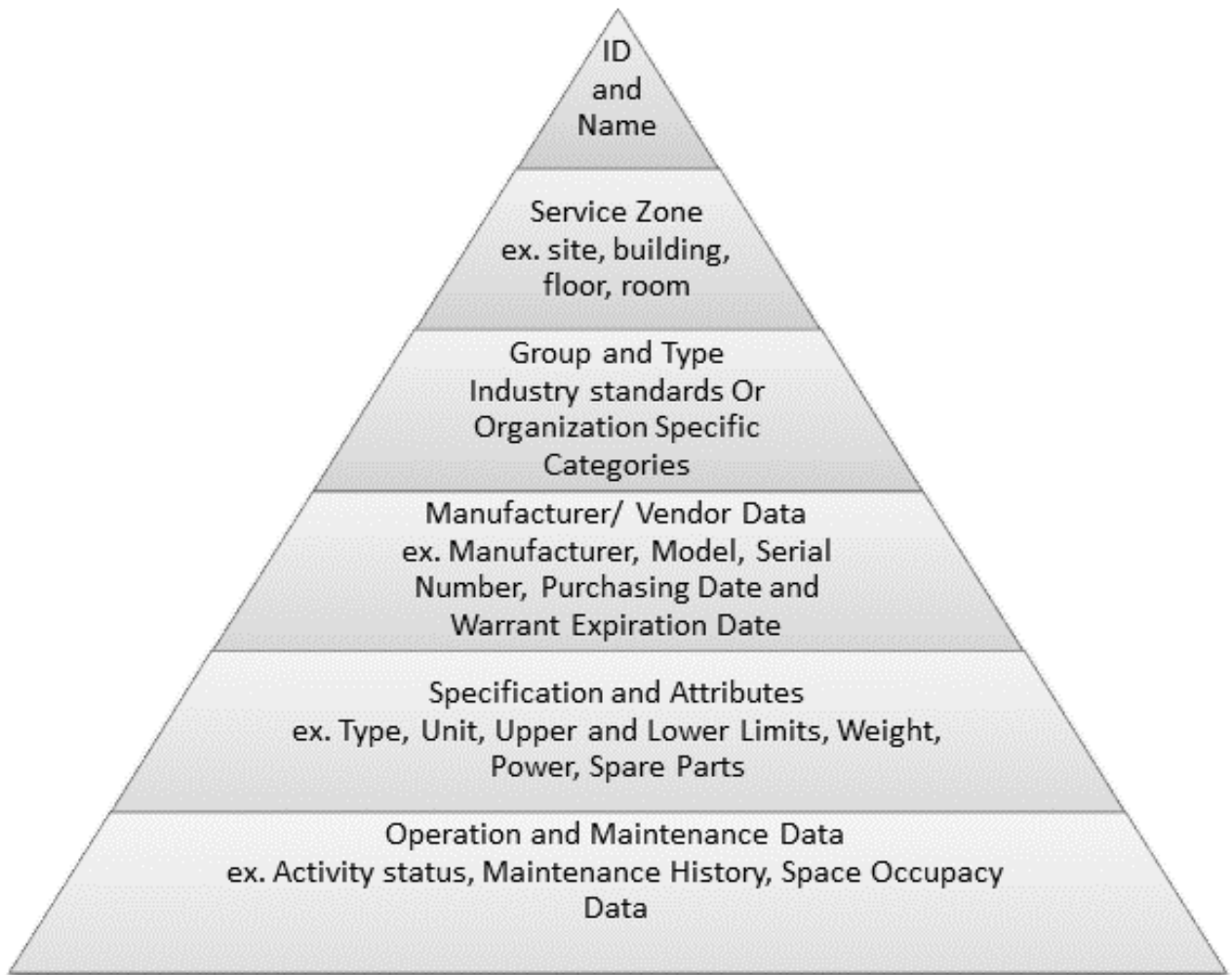


Figure 10: Data Structure of Non-Geometric Data Requirements. Reprinted from (Becerik-Gerber et al., 2012, p. 439)

3.6 Concluding Thoughts

In the above section, BIM has proved the practical use of its evolution in FM in completing the building cycle, not only designing and construction phases. Moreover, it pinpoints potential application areas, assistance, and the difficulties for BIM and FM integration. Effectively, BIM results in some areas are more productive than others; for instance, tracking down components, developing real-time data access, usability, and automatic generation of digital assets. BIM allows FM to make detailed and accurate decisions through the facility's whole life cycle around space usage, floor planning, equipment, maintenance assessment, energy consumption, and cost efficiencies. Building information modeling and FM link in the existing and substantial buildings' operation and management. BIM and FM integration makes the construction sector easier, significantly, in buildings as it promotes real-time access control as a start. The integration gives a more precise visualized layout to facility managers, aiding them in more accurate decisions and more manageable marketing plans. In addition, BIM is most critical in emergencies and the correct decisions that need to be taken quickly in buildings. All of this is based on the BIM's cost-efficiency and ability to best practices in maintainability and feasibility.

4. Future Policies and Procedures for Facility Management Development: A Case Study Approach

4.1 BIM and the Digital world

Building Information Modeling (BIM) framework requires a comprehensive 3D model that meets future management standards for advanced infrastructure assets. The Civil Engineering School (ETSICCP) infrastructure at the Universidad Politécnica de Madrid will be used as a case study in this project, built-in stages and calibrated with external educational knowledge and facility management (FM) criteria. The methodology for the project progresses from the ground up to a BIM-based complete FM system specialized in instructional planning in infrastructure, with real-time data synced with spreadsheets and a 3D model. Several possible control lines emerge from the findings, including COVID-19 BIM management or alignment with critical public transportation applications (mainly metro and bus transportation networks) via publicly accessible apps Application Programming Interface (API). The value of this inquiry is centered on creating a knowledge and control framework using a BIM model of the university campus. The project was planned for all staff, students, lecturers, managers, and personnel interested in its operations. Establishing and developing a modern BIM-based FM platform into the above technology could provide up-to-date synchronized information in classroom or sports facility reservations. Furthermore, real-time parameters such as occupancy or parking capacity are of great concern to the building's operations workers.

Future COVID-19 operating mechanisms might be introduced, and managing spaces and individual moves could be monitored and stored, resolving the issue of inconsistent individual instructions throughout the day. This study demonstrates and recommends the first management framework to monitor educational parameters in real-time and provide a BIM platform with the necessary specifications to host new management requests. Based on BIM, a comprehensive infrastructure of over 50 teaching facilities, 21 labs, and 4,000 graduates and undergraduates will offer various assistance and benefits. Social challenges can be resolved using the BIM-based management approach developed. BIM privileges are open for the first time to management and any

person who takes part in the everyday use of the facility. Real-time information, COVID handling mechanisms, booking, BIM, and sensor synchronization in conjunction with academic properties' location are now open to all users through the internet. Thus, an infrastructure living framework with varying functionality levels can be accessed based on the individual users, whether students, lecturers, or ETSICCP administrators (Pavón et al., 2020).

The improvement of BIM is a key aspect in the immediate future. In the context of infrastructure maintenance based on various software technologies, the past documents of the IoT/BIM models Union reveal notable advantages (Dave et al., 2018). BIM and IoT combine to have adequate knowledge in real-time, which is at the heart of Smart City (Anjomshoaa, 2014). The key focus of this term is the digital world, considering that Smart City is a continuation of Digital City. In this context, a BIM model compatible with public transportation networks, commuter lot, or weather patterns management applications enables the user with relevant data about the facilities and the Smart City in which it is implemented and consistent.

The ETSICCP prototype provides the opportunity to support IoT through sensor systems to provide real-time data to get the 'smart building' concept close to in terms of information management with high operational efficiency to improve BIM information with data that is extremely important in real-time infrastructures such as campuses, airports, and perhaps even hospitals (Carrillo et al., 2015).

4.1.1 BIM and Infrastructure Management

This project's unique approach thoroughly considers the strategies and analysis developed under the FM designation focused on real-world implementations of BIM management methodologies in various infrastructure facilities (Davies & Harty, 2013). The database part of the 3D model setup is regarded as the aspect on which the FM modules will be built (Gursel et al., 2009). While the quantity of resources listed in the infrastructure management database is significant, there are significant benefits to implementing BIM tools early in the process (Pavón et al., 2020).

The primary goals for model growth, either for modeling or for the management of information itself, are inter-operative ness between different sources regardless of the

initial process/stage, thereby lowering the traditional interoperability structure in the building industry (Alashwal & Abdul-Rahman, 2013). The life of FM software is focused on filling the gaps between BIM and infrastructure management (Naghshbandi, 2016), offering a much more effective approach for building management. Many assortments of FM strategies or basic instructions for various domains/fields or interested organizations boost BIM execution at the management level (Volk et al., 2014).

The developments of FM software depend on the Computer Aids Facility Management (CAFM) and the field software, including firefighting, energy management (Bottaccioli et al., 2017), and direct visualization model interaction will be one of the pillars of this chapter.

4.2 Educational Management in Universities

Management of significant public organizations based on and stressing the role of the FM has been examined in many studies. Anker Jensen proposed (2011) that FM should generate value for internal users while helping the core business, while a core business should add value for external customers. The Corporate Real Property (Dewulf et al., 2000, pp. 1–13) has a different description of FM.

The second most expensive university expenditure ranges from 5 to 15 percent in Europe was exploiting and maintaining the facilities (Heijer et al., 2014). Various surveys have shown that universities have broad capability areas, but their use rates are only about 40% ('How Are Countries Around the World Supporting Students in Higher Education?', 2012). In the 1960s and 1970s, the fundamental target for modern universities was to establish most university facilities in Europe with obsolete Smart Campus designs for 2020, which led to unsustainable technological conditions (Learning Environments: An Innovative Approach, 2013).

The framework is divided into three phases with three types of campuses: traditional, e-campus, and interactive digital campus. (Atif et al., 2014). The use of the internet to distribute the information to be acquired should be wide-ranging to access the e-campus phase easily (Atif et al., 2014). Digital campus needs an IoT technology environment, mobile terminal connectivity, RFID, and cloud storage.

There have been several benefits published in terms of digital campus income. Energy management (Alghamdi & Shetty, 2016) and cost savings in electricity, improved cooperation with other campuses, comprehensive university resources management, or campus location purposes map detail. Many of these advantages are made possible using RFID, IoT, 3D simulation, sensors framework, or web server (Atif et al., 2014).

4.3 BIM Mechanism in Educational Perspective

The concept of unifying static information into one database (classroom capacities, current interfaces, technical devices) and interactive data as locker duties, reading periods make the employees in charge of managing the ETSICCP fully available. Even then, implementing a modern management approach involves some challenges. Not only does the new management must be more effective than its precursor, though the required trained personnel should also set it up. Using this as a starting point, the complexity and size of the infrastructure raise the risks identified. (Pavón et al., 2020).

A gross area of 38,971m² has been considered in this project. It runs over 50 classrooms, 21 labs, and over 4000 students. There are two graduate schools, five post-graduation degrees, and two graduate degrees available.

The BIM approach developed in this analysis offers additional benefits in this context. The BIM approach requires all the organizations concerned to view the data through the internet. This grants the user on one site to navigate the infrastructure's services and environmental properties. In addition, COVID management, with the creation of a modern management system, all academic areas have been newly made available for 2020/2021. Thanks to a BIM model, the exact spatial distribution taking all geometry into account is detailed at the highest level.

Further, synchronization of sensors Real-time sensor information is connected to SQL databases coordinated with the BIM model, providing the user with all the data allocated in an infrastructure-specific location and a graphical manner. The procedure established allows the UPM to record all the equipment of the University and its correct

4.4 BIM-EDU Project

The 3D BIM model of the ETSICCP, mentioned above, was created as part of a more extensive BIM-EDU project. The priority of the BIM-EDU Project is to produce on the campus of UPM a 3D model ETSICCP. This context allows integration in managing the buildings and educational purposes of all knowledge of interest. This BIM model would assist the school's management personnel, enhance students' academic lives, facilitate their teaching activities, and combine the services and administrative personnel (PAS). The initiative includes a student group from the Smart Construction module, part of the Civil Engineering postgraduate master's degree. The goal is to create a strategy that satisfies all this university's current needs while also providing excellent training for developers who make novel recommendations and thus improving educational quality. As a result, a multi-phase project begins with data collecting and ends with a significant amount of data generated depending on whether the point will increase or drop. Therefore, as a design-oriented project, the BIM-EDU Project was formed (Brown, 2020).

4.4.1 Management and Simulation

The diagram below shows that the BIM-EDU project is built on two key aspects: BIM-based FM and infrastructure modeling. Infrastructure engineering not only created its models but also gathered all retrieving data systems. As a result, BIM-based FM includes using the BIM model to communicate infrastructure information to end-users.

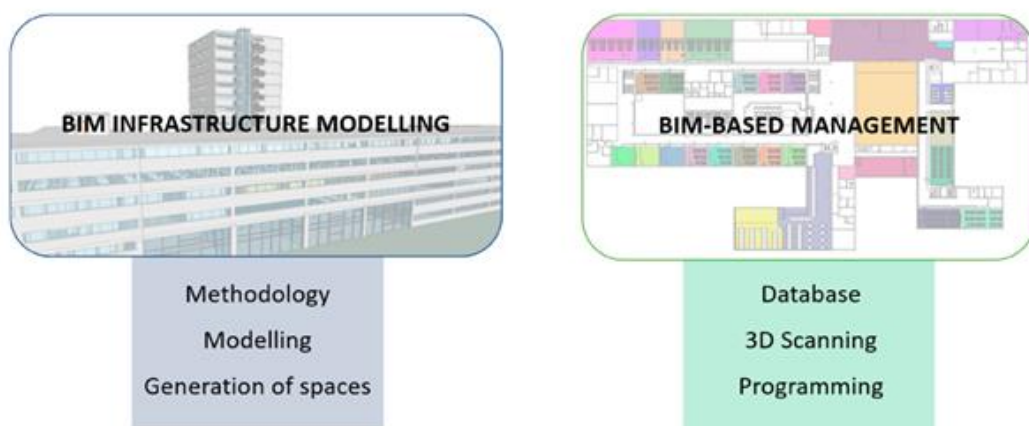


Figure 11: Building information (BIM)-EDU Project Building Model. Reprinted from (Pavón et al., 2020, p.7).

This project is centered on establishing and studying a practical management approach to BIM, considering only key areas applicable to UNE-ISO 19650-1 (International Organization for Standardization, 2018) and UNE-ISO 19650-2 (International Organization for Standardization, 2019). This project was implemented using a BIM Execution Plan (BEP) system of multi-phases. Various facets have been jointly considered, and a practical model based on the BIM technique was developed.

BEP has included comprehensive information on Project Information Requirements (PIR) and Asset Information Requirements (AIR). Other issues, such as a responsible schema or corporate knowledge requirements relating to legal issues, have not been considered due to the scope of this undertaking. The phases were formed by temporal coincidence independently (Pavón et al., 2020).

The first stage is the modeling stage. Because of the scale of the facilities, this was the most prolonged process. This process was subdivided to maximize productivity based on the level of information used in the finished product. The second is the base model, which oversees the simulation of the architecture of the infrastructure. During this point, the data quality reported was poor. For this process, the BIM model file contains modeling of typical architectural components, such as walls, floors, windows, or roofs (Pavón et al., 2020). Third, the detailed model. It considered essential elements that permitted the infrastructure to be differentiated and identified. During this process, the BIM-based file starts with unique housing elements such as desks, lockers, pictures, projectors, or materials separately modeled and then included into the conclusive infrastructure model file, then followed by data assignments 40-day integration to the model.

The integration can happen through spreadsheets that create a database consolidated with a timetable where all time plans for the academic year 2011-2020 for all grades and four masters are completed for each degree.

The database could be modified or improved on an as-needed basis, but continual changes at this point would be incompetent. Eventually, after all the previous tasks have been completed, the drafting stage takes place. The project's language and report must be completed to implement the findings regarding gains and simulation, and methodology disadvantages (Pavón et al., 2020).

4.4.2 AutoCAD, BIM Linking, and University Main features

BIM modeling software was used to begin modeling using BIM methodology using existing and improved knowledge. The modeling of various types of infrastructure varies from the typology of the construction and the applications and the workflow that must be tailored to the existing resources. In this context, with the primary circumstances mentioned, it was possible to import data in a CAD format that referred to the plan views of 10-floor plan levels preceding the required separation.

To discover any omissions or faults in geometric infrastructure, a redesign of CAD data is required at first. Then, applications such as BIM and CAD must be examined. Furthermore, because the BIM software model needs individual CAD information at a significant level, CAD information revamps were created to improve the integration of CAD data into the BIM setting. Furthermore, the available CAD detail only pertained to the floor plan and sectional measurements. Therefore, it was obtained in situ to include actual height to BIM heights, meeting the flow chart criteria (Pavón et al., 2020).

Two major issues were presented to achieve the main goals of the case study shown in this research. The first was about the simulation of infrastructure and the implementation of the ETSICCP 3D model. The second challenge was introducing appropriate tools for facilities maintenance using the building's BIM model.

ETSICCP had a total land area of 38.970.84 m². With a net surface area of 5,289.329 m², the productive area was 32,631.23 m². The most notable rooms, according to the table below, are 26 and 27. ETSICCP is used by about 4000 students at various degree levels, including graduate, master's, and doctoral. These figures demonstrate the magnitude of the school's facilities, apart from the enormous potential for introducing innovative management, room practices, repair equipment, and staff relationships while being aware of the impact that a BIM technique implementation will have, allowing a constant link between the model and either a tablet or a SQL application server, so that all model details are instantly reproduced in the database and vice versa (Pavón et al., 2020).

Table 4: Teaching Space Surface. Reprinted from (Pavón et al., 2020).

Name	Surface	Name	Surface
José Echegaray Room	69.61 m ²	Room 24	101.16 m ²
Room 1	238.88 m ²	Room 26	329.94 m ²
Room 2	115.08 m ²	Room 27	330.64 m ²
Room 3	117.68 m ²	Room 28	57.82 m ²
Room 4	238.87 m ²	Room 29	59.52 m ²
Room 5	57.82 m ²	Room 30	58.78 m ²
Room 6	59.52 m ²	Room 31	58.78 m ²
Room 7	58.78 m ²	Room 32	57.22 m ²
Room 8	58.78 m ²	Room 38	100.10 m ²
Room 9	57.22 m ²	Room 39	100.02 m ²
Room 11	54.90 m ²	Room 40	58.67 m ²
Room 12	56.39 m ²	Languages Room	57.26 m ²
Room 13	56.39 m ²	Room 45	103.25 m ²
Room 14	56.39 m ²	Room 46	101.16 m ²
Room 15	56.39 m ²	Ag. Betancourt Room	56.70 m ²
Room 16	56.39 m ²	CAD Room	55.67 m ²
Room 17	56.39 m ²	Exam room	1652.12 m ²
Room 18	56.39 m ²	Computers room	90.56 m ²
Room 22	113.49 m ²	Turing Room	121.18 m ²
Room 23	103.25 m ²	Total	5289.32 m ²

4.5 University Information Model

4.5.1 Internal and External Modeling

The geometric identity of the wall components gives the infrastructure this process was essential. Internal and external walls or façades define the internal and external infrastructure skeleton impacting various spatial control component features. The modeling followed the rules of the BEP, which allowed context and management principles. Table 5 indicates the naming of different product forms.

Table 5: BIM Execution Plan (BEP) Nomenclature Extract. Reprinted from (Pavón et al., 2020).

Component	
Name of The Component	Name Of the View
Wall	A-wall Thickness and Units
Curtain wall	A-Curtain and location
Pillars	A-Panel material
Doors	A-pillar dimension A × dimension B
False Ceiling	Aft and Location
Windows	Dimension A × Dimension B and units
Res Of the Objects	BIM software name by default

With a small proportion of simultaneity compared to previous stages, the simulation of the components associated with each flooring device was considered in the base modeling step above. As previously stated, modeling was done level by level, and this approach was critical due to the unique characteristics of “wall” components. The first impulse is to build walls, particularly façades, that account for the entire height of a front wall from level 0 to level 3. This approach's modeling can help with content measurement errors at a stage. This problem is caused by BIM wall accounting software, but if the adjustment is only meant to influence level 2 of the infrastructure, the walls from level 1 to level 3 will not be included. To account for it, the modeling must be done floor by floor, ensuring that the façade is represented in multiple walls, one from level 0 to level 1, another from level 1 to level 2, and yet another from level 2 to level 3. Accounting can be precise in this manner regardless of how filtered the data is. (Pavón et al., 2020).

Modeling followed the stated approach to provide a layout for the university that could be used for space management and prospective infrastructure funding alterations or revisions to reduce the noted faults. As seen in figure 13, the remodeling of the corridors brings classes 26 and 27 closer together. In figure 12, the reform-affected walls are shown in blue. If the wall has been modeled from level 0 to level 2, the affected wall is comparable in levels 0 and 1, ending in level 2, resulting in faulty modeling, as seen in figure 13

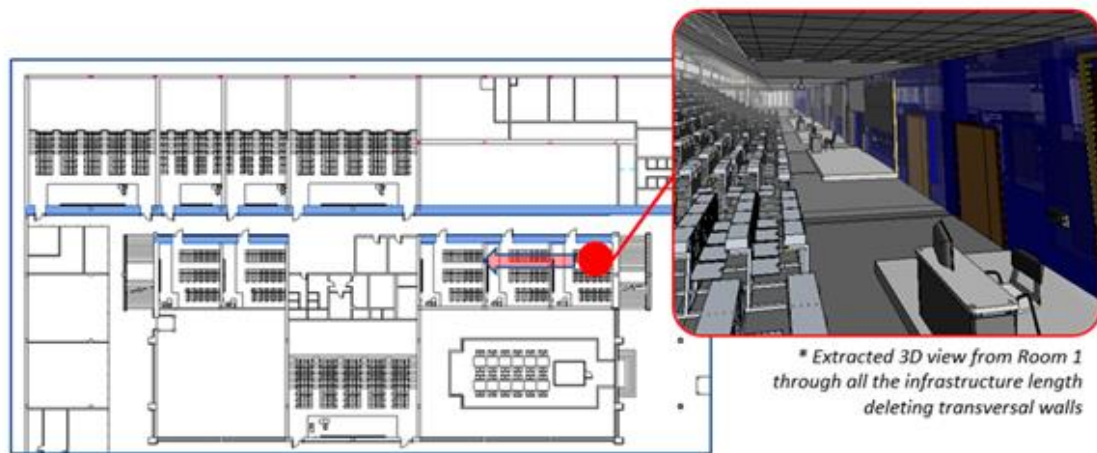


Figure 12: Corridor Rehabilitation. Reprinted from (Pavón et al., 2020).

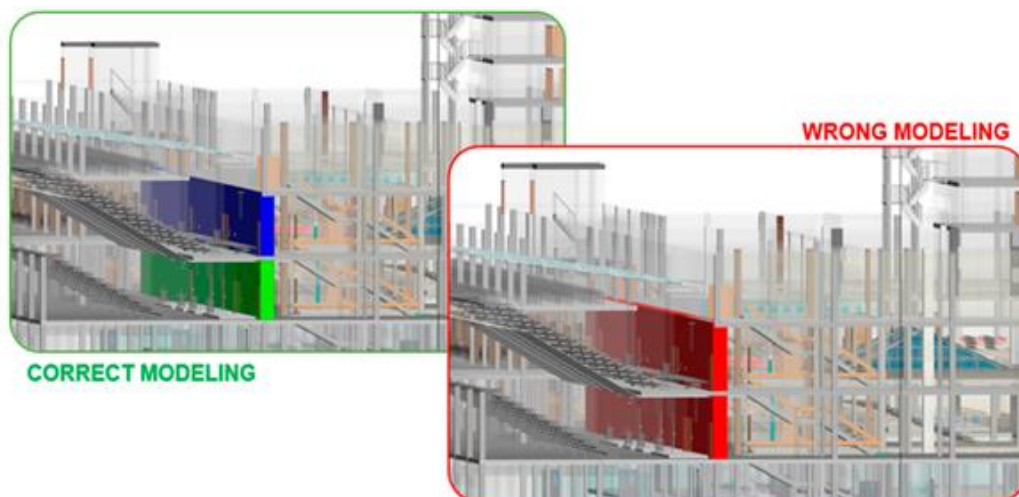


Figure 13: Accurate and Inaccurate Wall Modelling. Reprinted from (Pavón et al., 2020).

This wall does not appear in the quantity list once the data is sorted by the stage and by the acting field. Table 6 demonstrates an overview of the amounts and budgets that

are modeled. The reform's unit price is the price suggested by the official Madrid price generator.

Table 6: Budget Based on Inaccurate Modeling. Reprinted from (Pavón et al., 2020).

Object	Area m2	Volume m3	Length(m)	Rehabilitation Cost €/m2	Total cost €
Basic wall	33.05	14.02	23.8	45.81	1605.46
Basic wall	22.00	22.00	5.0	45.81	1007.82
Basic wall	20.42	4.08	4.5	45.81	935.26
Basic wall	29.20	5.84	7.7	45.81	1337.65

Table 7: Budget Based on Accurate Modeling. Reprinted from (Pavón et al., 2020).

Object	Area m2	Volume m3	Length(m)	Rehabilitation Cost €/m2	Total cost €
Basic wall	33.05	14.02	23.8	45.81	1605.46
Basic wall	22.00	22.00	5.0	45.81	1007.82
Basic wall	20.42	4.08	4.5	45.81	935.26
Basic wall	335.60	335.60	79.8	45.81	15,373.74
Basic wall	29.20	5.84	7.7	45.81	1337.65

As all simulation options are compared, the mistake impacting walls modeled on several levels is distinctly noticeable. As shown in the figure below, this mistake will result in significant cost disparities.

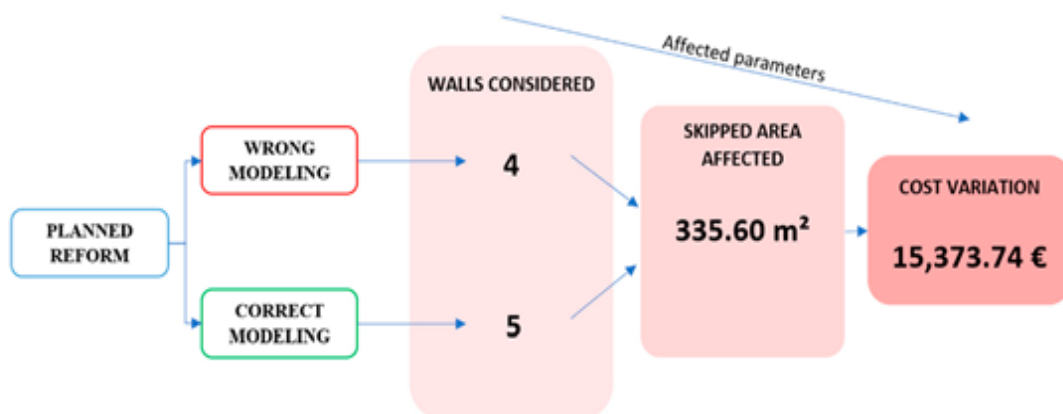


Figure 14: Parameters Changes by Modelling/ Cost Disparities. Reprinted from (Pavón et al., 2020).

4.5.2 Space Creation

The school spaces can be divided into several different properties. Some of them are automatically generated, such as place, volume, and position with reference to the floor level. This real-world data can be extracted and transmitted to databases. The assigning of data specific to the requirements of the organization may be extended manually. The department to which the room is assigned; the UPM alphanumeric code that logs all University-owned rooms are some of the model's creations and indications of new parameters. In addition to the connections available for teaching purposes such as USB ports, automated systems, updated versions, video projector versions, Etc. (Pavón et al., 2020). Simultaneously, classroom capacity can be altered depending on the type of space operation.

With these latest designs of the parameters and their features, it was possible to draw up data sheets relating to the dominant properties of each classroom, as seen in figure 15. These data sheets are beneficial for the teaching staff and administration. A summary table is shown as a sample. It must be noted that the model is linked to it, so the impacted datasheet immediately reflects any changes in the BIM model. This knowledge transfer is made possible using tablets linking the BIM model with the datasheets (Pavón et al., 2020).

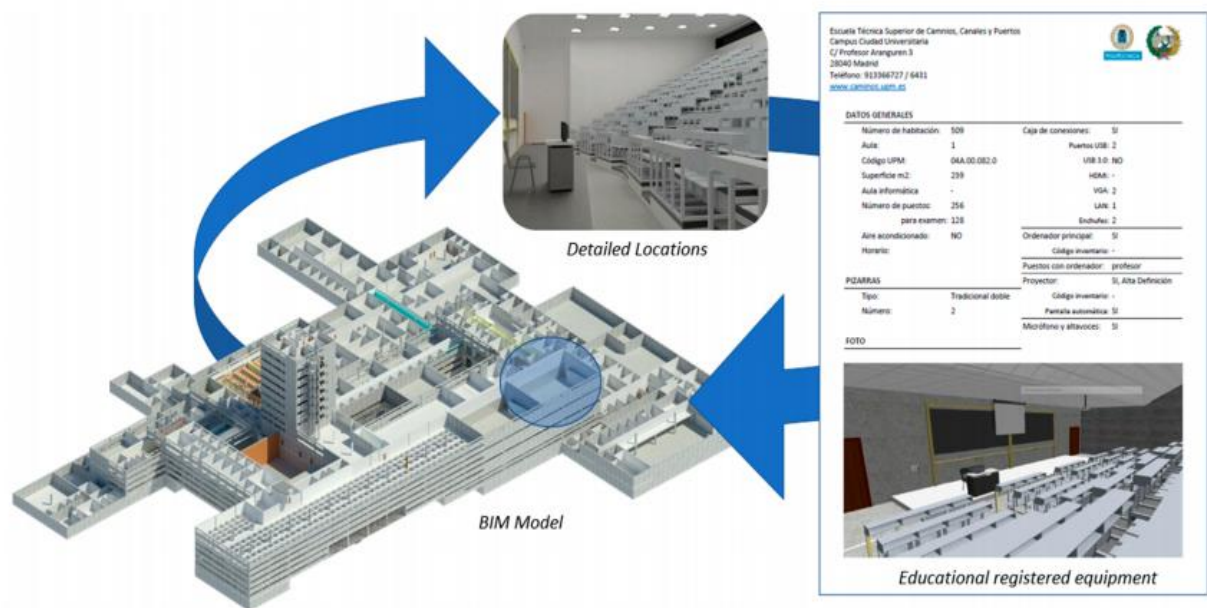


Figure 15: Room sheet BIM model, Detailed Spaces, and Information Management. Reprinted from Pavón et al., 2020).

The minimal safety distance between persons is one of the primary considerations against the present COVID-19 revival. This aspect is complicated regarding compliance inside specific facilities such as campuses, airports, or hospitals involving numerous individuals. To comply with that measure, the busier areas within the building need to be known, considering the different times, and providing users with up-to-date data on occupancy rates and the busiest areas of the building, along with up-to-date information and the best way to get to their destination (Pavón et al., 2020).

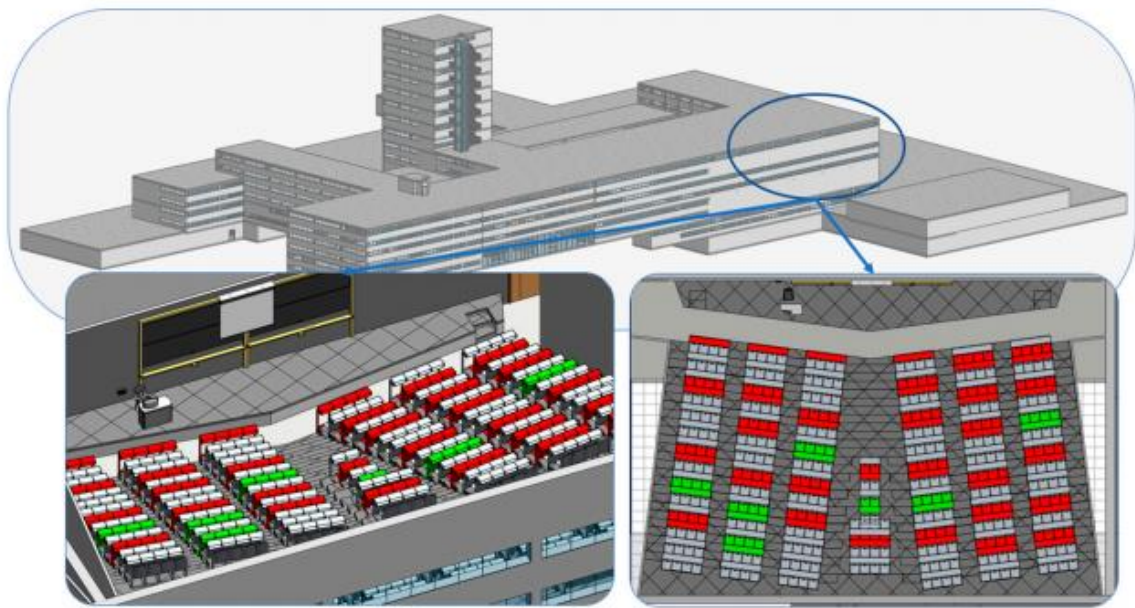


Figure 16: Visualization of the BIM Model's Seat Reservation Function. (Pavón et al., 2020).

4.5.3 Sustainable Development: Lockers Synchronization

The possibility of combining data sources based on BIM and IoT is relatively recent. BIM and IoT data have complementary insights into the project, supplementing each other's shortcomings. At the component level, BIM models provide high-fidelity project representations. BIM models are highly accurate operational data collecting materials, properties, and a space organization built to collect abstract geometric items, visual perception, and versatile data features. IoT data develop this database by providing the current construction processes and operations with real-time and trackable status (Tang et al., 2019). The BIM model and the factors taken into consideration during the modeling phase allow a standard management system based upon the BIM model, for example, the proximity of the student locker to its classroom, considering the

parameters never previously considered for the independent management (Pavón et al., 2020).

The synchronized data sampled from sensors are highly unpredictable but encircles location, physical dimensions, temperature, Etc. These data are generally structured over time as time-series data sources with various sensor points, often with an organization of higher ranks, Etc. Both IoT and BIM data can be accessed via various methods, such as manual systems interfaces, applications-related API programming, future computer storage connections, and open-standard exporting. A range of open guidelines emerges in both the IoT and BIM sectors (Tang et al., 2019).

In addition to classroom management, the management of an educational infrastructure covers multiple dimensions. The physical characteristics of this vast extension building make it much more necessary to provide comprehensive and effective management above and beyond the entire academic arena. There are several cleaning crews at the school. Some operate during the evening and others at night and repair teams for electronic systems, heating, air conditioning, mechanical and electrical equipment, and personnel, amongst many others. Different management methodologies shall further improve the enhanced model and integrate the delegated knowledge with time (Pavón et al., 2020).

4.6 Tyren Building, BIM Findings

4.6.1 General Features

Tyréns headquarters, the 9,500 sqm gross floor area, is owned by Tyréns Foundation in Stockholm. Einar Mattson and Tyréns AB are the facility managers of the building. Both Mattson and AB supervise the 10-story building with a gross leasable area of 7,500 sqm, including a 1,500 sqm gross leasable area for each floor. There are 1000 wireless sensors scattered along with the building, varying from light to temperature, humidity, motion, electricity, sensors, and plugs. The building uses a 3D Revit file as the main drawing format using viewer Maint 3D (Nguyen, 2016).

The 10-story structure has a single basement. There are six standard office floors (1st–6th), two basements, one meeting room level, and a technical area on the rooftop level.

Inside the 6-office-floors, there are several additional internal conference rooms in an alternating cubicle area. In 2015, a pilot project to implement BIM applications and various applications during the operation phase was installed in the Tyréns building with over 1,000 sensors. The purpose of this project is to uncover more aspects of the building used in its day-to-day work. The project included collaborators in system improvement and hardware such as Yanzi network (sensors developer), SVS Innovations (Facilities management viewer – Maint3D), IBM (Maximo assets management), Microsoft (Power BI Analytics tool) (Nguyen, 2016).

4.6.2 Wireless Sensors Network and 3D Building Model

A 1000 wireless sensor facility was installed in Tyréns in 2015, three types of wireless sensors are included in this system, for instance, a climactic sensor (measuring temperature and humidity level), a motion sensor (measuring movement), and adapters - measuring and controlling energy consumption-. A building-mounted sensor was connected using the IDs of the building to the specific objects or space names of the building (known as a building-mounted sensor was connected using the IDs of the building to the specific objects or space names of the building (known as the GUID) through an IFC data installation feature on the Maint 3D viewer tool (Nguyen, 2016).

A pilot scheme was used as the Revit model (a BIM program format) to optimize the post-construction BIM structure in the building in Tyréns headquarters. The IFC and COBie data standards are then exported from this Revit model to import the appropriate monitoring tools/applications. Accordingly, the basic IFC format includes both geometry and textual details of each object (Nguyen, 2016).

In addition, design desks and stalls make it possible to realize the number of actual rooms designed by visualizing the number of persons. In conjunction, the connection of the sensor identification to establish GUID devices can be made simpler. Motion sensors are installed in the meeting rooms in tracking motion and accessibility, in personal desks, or in seating (Nguyen, 2016).

should not, in this case, be considered physical objects to be adapted to the building model (Nguyen, 2016).

Maximo is IBM's software product for business assets operation, maintenance, and disposal. Maximo application in Tyréns must handle all 3D model properties in this building and all object knowledge to support the operational and repair work orders management. To this end, the format is transferred using the Revit Tyréns model until it is imported to Max COBie data Maximo (Nguyen, 2016).

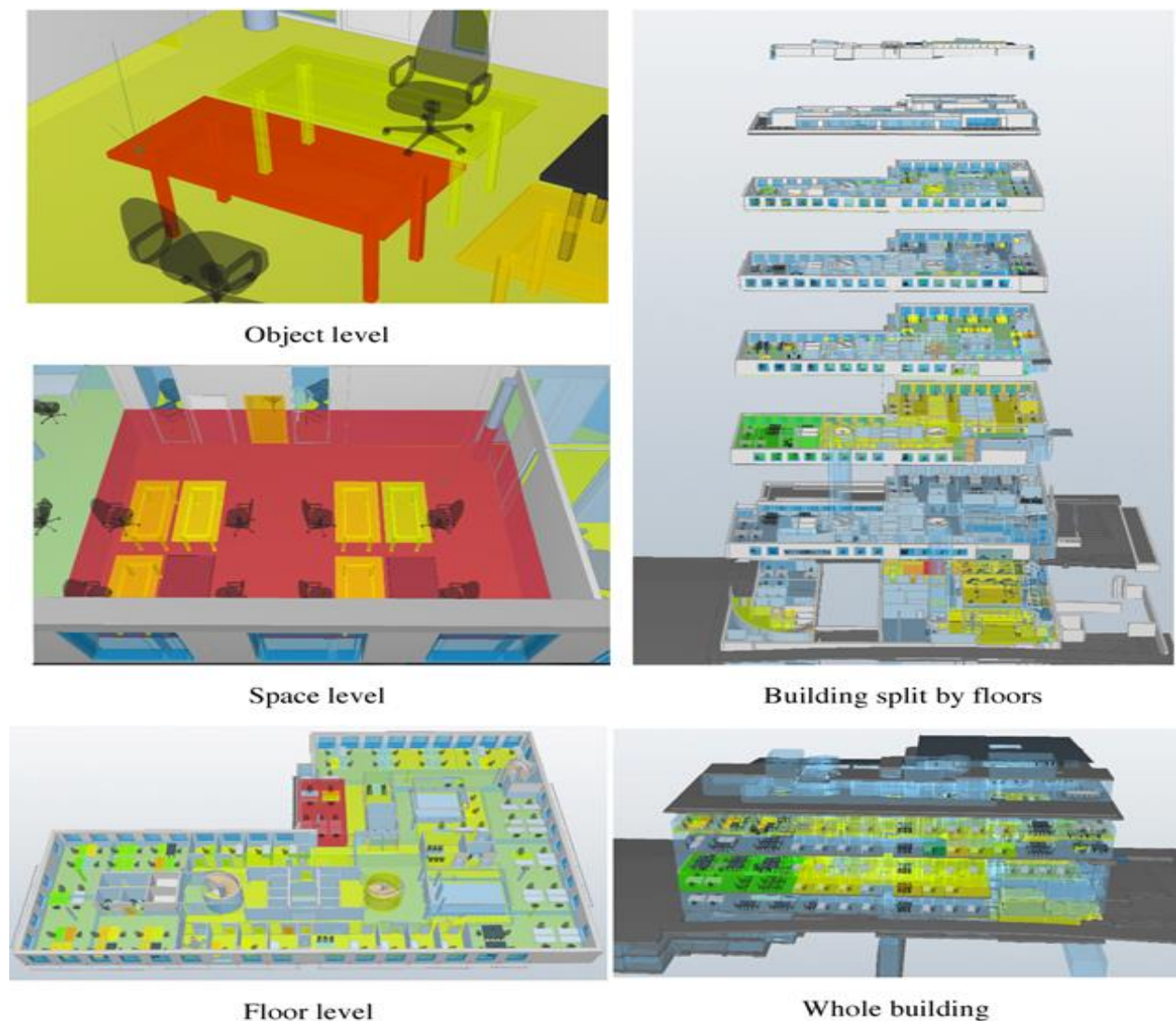


Figure 18: Visualization with Colouring at Hierarchical Representation. Reprinted from (Nguyen, 2016).

4.7 Concluding thoughts

Public organizations strive to increase their management consistency and performance. Even though conventional paper-based methods are used, minor changes were made in technology implementation, such as real-time data or identification systems in the last period.

A complete BIM model was carried out as a part of the ETSICCP study with all parameters correlated with day-to-day management activities. This FM BIM-based system can handle classrooms, sporting installations, lockers, or other location details. Its system includes reservations, scheduling, temperature, humidity monitoring, room capacity, or machinery maintenance.

BIM system offers a highly effective process and a more appropriate organizational flow of data for all participants involved in infrastructure managing, especially in complex buildings such as university venues. Management workers could navigate both spaces and internal movements due to the latest management technologies, including a BIM model and Big Data databases. Furthermore, upcoming technologies, such as COVID-19 containment protocols, may be introduced.

The vast amount of information included in the model for elements and specifications, i.e., air-conditioning, the connection box, projector features, capacity, and the official website documentation, enabling the speakers to choose the optimum room with much higher variables than standard approaches. The BIM model contains the most accurate geometrical details as the central point of the management approach, allowing users to display real-time data, such as tracking COVID-19 protocols.

This FM BIM-based model is implemented and open to both infrastructure personnel and users. A single management framework controls rooms, tools, or climatic factors to be controlled. The sensors to measure temperature, humidity, and the room's capacity are not yet installed in all the rooms, although the BIM-FM was developed and supported this advancement. Prototypes and the implementation can be accomplished and monitored relying on future investments.

5. Reducing Operational GHG Emissions through FM

5.1 Greenhouse gas emissions

Every significant advancement in human civilization has an impact on the environment. Some effects have a direct and indirect global impact on the environment's close parameters, while others have direct and indirect global implications. For example, even though construction is a watershed moment in human history and the backbone of many economies, it comes at a price (Lu et al., 2018, p. 144). The construction industry is responsible for 36% of total global final energy use (Global Alliance for Building and Construction & International Energy Agency, 2017). In addition, construction generates one-quarter of the solid waste generated at landfilled sites (Lu & Yuan, 2011, p. 1253), resulting in increased worldwide greenhouse gas emissions. Greenhouse gases are gases that have a higher-than-average concentration in the atmosphere, trapping heat. Carbon dioxide, methane, nitrous oxide, and fluorinated gases are the four major greenhouse gases (Overview of Greenhouse Gases, 2020). The Global Warming Potential (GWP) is the total amount of energy that a gas absorbs over a period, usually a decade (Understanding Global Warming Potentials, 2020). Furthermore, the GWP should be highlighted, and the inclination to cause global warming to have a direct relationship (Greenhouse Gas Overview, 2020). After reaching a specific concentration or a "warming" effect, each gas has a particular impact.

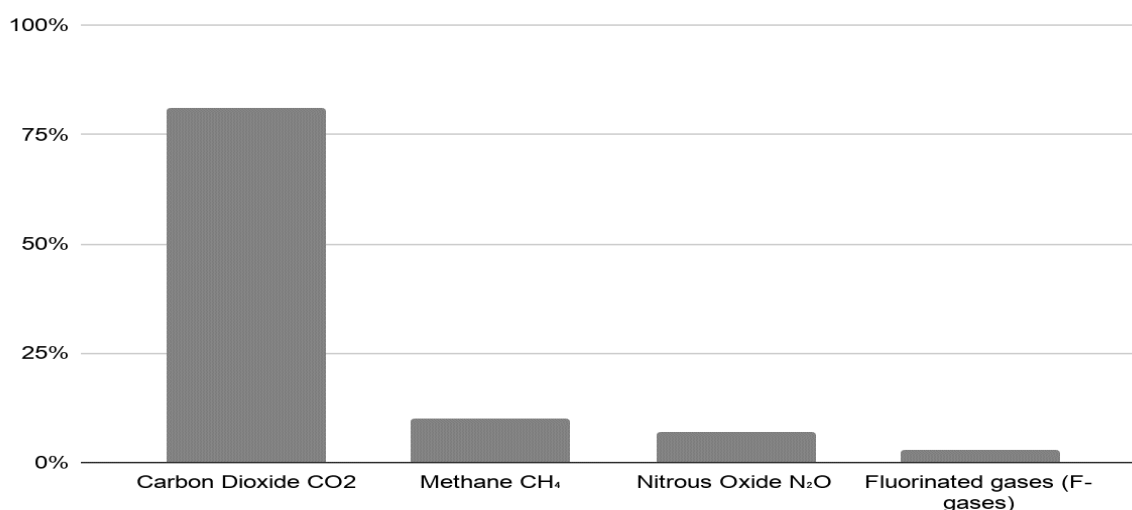


Figure 19: Greenhouse Gases. Reprinted from (Overview of Greenhouse Gases, 2020)

To change the CO₂ counterpart, a CE element (carbon emissions) is used (De Wolf et al., 2017). The CE factor refers to the amount of greenhouse gasses produced from a substance or energy absorbed by one unit. In building operations, CE considerations connect a variety of materials and energy with CE. Sees CE influences will shape the CE of a building project during the materialization phase. Table 8 shows the IPCC CE for National Guidelines for Greenhouse Gas Inventory (2006).

Table 8: Emissions Factors in Carbon from Various Materials and Energies. Reprinted from (Hao et al., 2020)

Materials	CE factor	Units
Concrete	321.30	KgCO ₂ eq/m ³
Steel bars	2617.00	KgCO ₂ eq/t
Steel plates	2702.00	KgCO ₂ eq/t
Blocks	232.24	KgCO ₂ eq/m ³
Stones	232.24	KgCO ₂ eq/m ³
Diesel	2.73	KgCO ₂ eq/L
Electricity	0.78	KgCO ₂ eq/kwh

Many policies and laws, such as waste management and lean builds, have been imposed, implemented, and adopted in this way to achieve low levels of carbon emissions (CE) from the building sector (Bao et al., 2019, p. 19; Ahmad et al., 2019, p. 1093). As a result, there has been a technological breakthrough in design concepts and management in the building industry. For example, prefabrication construction, sometimes known as "industrialized building," is a commonly utilized approach for reducing carbon emissions. Prefabrication construction relies on moving building components from "in-site" to "off-site" manufacture in factories before placing them on construction sites. For example, as parametric or modular integrated units, multiple materials are joined to produce a specific aspect of a more extensive installation (Röck et al., 2018, p. 154)

One of the recent technologies that have shown effective and efficient results is BIM. BIM's ability to provide physical and virtual insight into the construction throughout its phases can lower the CE of constructions (Wong & Zhou, 2015, p. 163). Some studies were conducted for a more precise application of BIM in reducing carbon emissions. One study by Röck et al. (2018, p. 154) schemed an advanced visual scripting mechanism via connecting Life Cycle Assessment (LCA) with BIM to provide designers with

potential hotspots for enhancing the construction's impact on the environment. A further methodology indicates that data acquisition and data processing of geometry and thermography would automatically generate textured as-built models (Lagüela et al., 2013, p. 232). Another study examined the relationship between building orientation and energy consumption while looking for the most efficient design alternatives (Abanda & Byers, 2016, p. 518). However, these studies have focused on residential buildings and constructions, neglecting official buildings (K. Lu et al., 2019, p. 6274).

Moreover, these studies focus more on CE from construction projects than the expected CE decrease via prefabrication using a BIM-based model (Hao et al., 2020). A more detailed scope will be discussed further and focus on the BIM-based models to estimate the six different emissions: greenhouse gases, smog, particular matter, ozone-depleting particles, eutrophication particles, and sulfur dioxide. In such a manner, total and indirect emissions are estimated throughout the whole construction process, starting from the manufacturing phase to the transportation phase to the construction phase, then the operation stage, and finally, the demolition phase (Marzouk et al., 2017).

Even though some previous studies have highlighted estimating CE, there is still no systemic analytical framework, especially in the Building's Life Cycle Carbon Emissions (BLCCE) analysis in different climates. This research, therefore, suggests a CE measurement system focused on BIM and LCA, building up in four phases: maintaining the CE limit in a life cycle; providing a CE coefficient Chinese buildings database, and using Revit and Green Building Studio; measuring CE continuously; and interpreting CE levels (K. Lu et al., 2019).

Thus, the construction, operational, and demolition stages add to the BLCCE concept, as explained in figure 20.

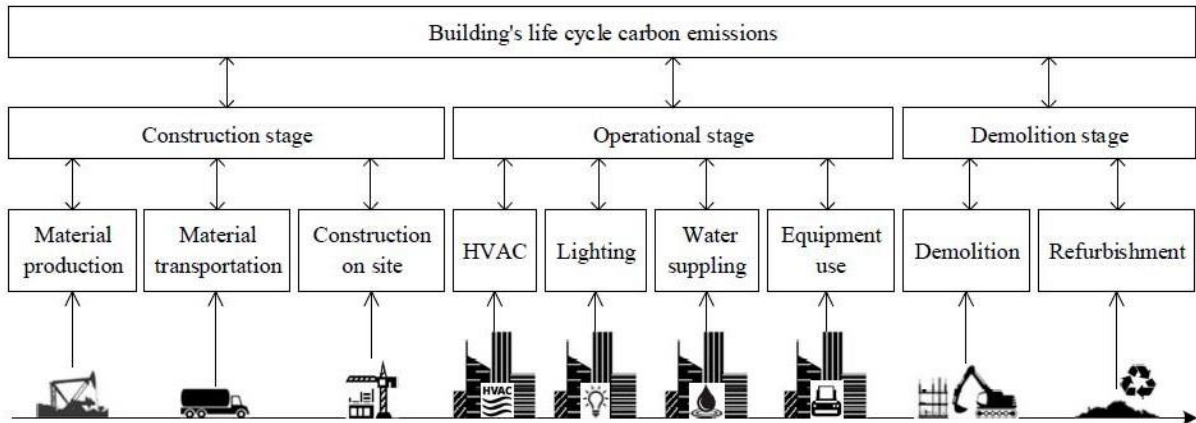


Figure 20: Composition of BLCCE. Reprinted from (K. Lu et al., 2019).

5.2 Facility Operation Emission

The construction sector accounted for 38% of global energy-related CO₂ emissions by incorporating emissions from the building industry to top operational emissions (United Nations Environment Program, 2020). As shown in various graphs during the research, natural gas and energy are primary producers responsible for pollution throughout service for all purposes. Inger Andersen, the Executive Director of the UN Environment Program (EUP), stated: The rising emissions from buildings and the construction industry stress the immediate need for a triple initiative to decrease energy consumption in buildings and the energy sector drastically and to develop materials strategies to cut CE of the energy sector (UNEP). The total carbon dioxide equivalent can be calculated by multiplying each greenhouse gas amount by the equivalent global warming potential (Understanding Global Warming Potentials, 2020).

The best-case indoor climate condition for building users is the comfort zone that includes several indoor environmental categories: sound and light systems, temperature, air quality, cleaning and maintenance, Etc (Huizenga et al., 2006). In this manner, two indoor climate drivers are highlighted for further detail: carbon dioxide (CO₂) and temperature. CO₂ (parts per million/ppm) sets a ventilation system benchmark and air quality, while temperature (degree Celsius/°C degree) measures the HVAC system (Nguyen, 2016).

Indicators of insight functions and decision-making combine primary activity, information usage with strategic thinking. Accordingly, in a Harvard-based

experimental study, CO₂ prompts direct negative leverage over the occupants' understanding and decision-making performance. In the Harvard experiment, the Harvard school of public health showed a correlation between the high CO₂ levels in controlled office spaces and a reduced cognitive functioning in different domains (Alavi & Leidner, 2001). The study showed that with an average 400 ppm CO₂ increase, there is a 21% fall in the cognitive functions in the three CO₂ levels: 550 ppm slightly above intermediate CO₂ outdoor level; 945 ppm average typical indoor CO₂ level; 1400 ppm high, however, average, typical indoor 8 hours CO₂ level (Alavi & Leidner, 2001).

Equally important is the increasing temperature (°C degree). For instance, activities that require complex understanding, such as planning, are negatively affected when the subject/person is exposed to a slight rise in temperature, from 22°C to 24°C degrees, for more extended periods (Zhang & de Dear, 2016). Both temperature and CO₂ are key parameters that directly link the user's safety and welfare to the physical office environment and the office's duration. Therefore, controlling CO₂ levels and temperature are crucial to managing an office building; this can be done via automated control systems steering systems (HVAC) (Nguyen, 2016).

5.3 Tyréns Headquarter Building, Stockholm Case Study

BIM and IoT integration to increase building productivity from an occupant perspective (Nguyen, 2016). In particular, there was a special interest in emissions of CO₂ and the ambient temperature. Nguyen (2016) performed a questionnaire on assessed air quality and the relationship between the air and the occupants to demonstrate the value of CO₂ levels and temperatures. Two hundred twenty-six participants replied to a 4.2% error margin. It dealt with using the Meeting rooms on the 0th floor, where 69% of people spent less than an hour a day, while another 19% spent an hour. One conclusion was that the doors are kept closed because of either the gatherings privacy or removal of the outside noise. However, 90 percent of participants must not leave the door open. Therefore, an effective HVAC system is essential to ensure good air quality inside these closed spaces (Nguyen, 2016).

However, participants indicated insufficient air quality when the conference room doors were opened on the 0th floor. 35% allowed doors to be opened for air re-opening in the room and the doors to be used as additional ventilation. Conversely, about 70% of the participants did not meet the indoor temperature (Nguyen, 2016).

In conclusion, the contributions from 226 participants in a meeting room on the 0th floor of Tyréns's headquarters indicate low temperatures and low air quality. The answers showed that the space was uncomfortable and air quality. At the beginning of the meetings, the rooms were too cold and ended hot as more people joined and spent more time inside, with an inadequate response by the heating/cooling systems. In reality, 70% of the participants were deceived by the air temperature and 48% by the air quality. Though more than half were satisfied with air quality, some complained about the lack of adequate conference rooms (Nguyen, 2016).

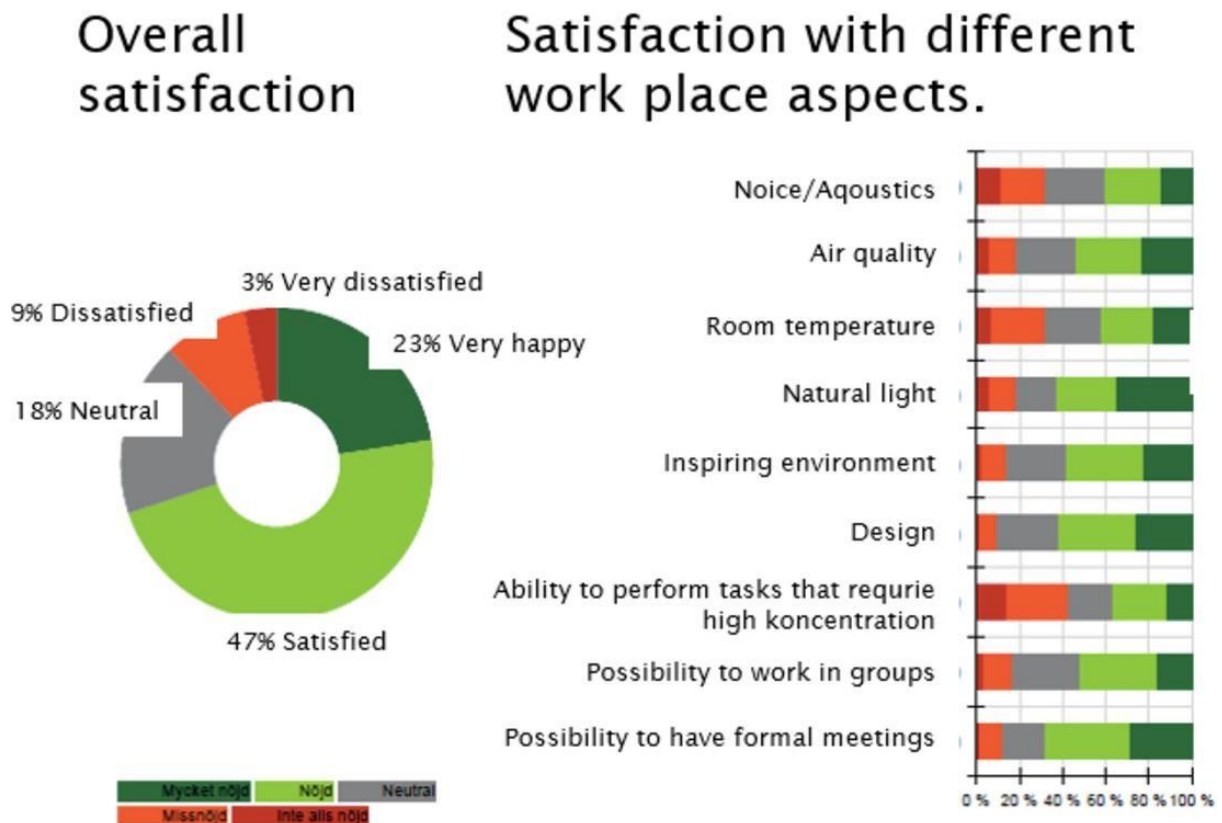


Figure 21: Tyréns Survey graph. Reprinted from (Nguyen, 2016)

According to the assumption, these comments were made regarding temperature concerns when they should have been made in the context of air quality concerns. Given that the loss of oxygen is generally linked to an air shortage, air quality is a

problem. The presumption may be perceived that some participants as 'climate content may misinterpret the word 'temperature.'" Otherwise, the visual sensations of low temperature and low air quality could not be differentiated. Additionally, with 90% of participants reporting a need for meeting rooms with locking doors to protect secrecy and anonymity for their meetings, it necessitates an excessively sufficient indoor temperature in closed spaces. 80% of participants have reported that the temperature and air quality in the Tyréns building significantly affect their efficiency and productivity (Nguyen, 2016).

The analyzes of this questionnaire were used as a basis for implementation. In a particular meeting space, many participants are unhappy with the temperature and air quality of the meeting room and some other facts from informal interviews with Tyréns staff (Nguyen, 2016). Temperature and CO2 sensors have been designed to measure the sum for certain variables.

5.3.1 Implemented Objects and Materials

Two meetings were taken as the subjects to be measured to determine the temperature and CO2 levels in room 052 when the room was inhabited. These two meetings took place within three weeks of the sensor's installation.

The following guidelines were used to determine which meetings were sampled:

- **Time:** Sessions were held regularly for 4-5 hours per day simultaneously for several days continuously with break and lunchtime to round up the CO2 and temperature accumulation.
- **Used Capacity:** 60%-100% of the room's capacity equivalent to 8-12 people.
- **Targets:** Two separate meetings were held in room 052 under two different circumstances. Meeting A is with an opened door with 11 occupants. The meeting started at 9 am and ended at 2 pm. While meeting B started from 10 am till 2 pm with 9 occupants and a closed door. (Nguyen, 2016).

The implementation was initiated on the 0th floor of the Tyréns headquarters, where access points and the gateway had been built already. Moreover, when the power is

provided and mounted, the sensor will self-configure and connect to the network. (Nguyen, 2016).

- **Sensor:** In this implementation, an Air sensor is used to measure the two indoor: temperatures and CO2 levels. It is an integrated power plug wireless sensor.
- **BIM:** After changing additional pieces of furniture (chairs and tables) with geometric and semantical details, an IFC file is being exported from the Tyréns building model Revit.
- **Tool:** Maint3D is thought to be comfortable and straightforward for inhabitants to use on a mobile, tablet, or device, with no complex fixed facilities requirements. As a result, Maint3D was selected over other software for this implementation (Nguyen, 2016).

5.3.2 System Architecture and Location

After installing Maint3D, air sensors are automatically linked to the access point and Maint3D function on the 0th floor. The configuration is outlined by an existing IFC data file platform derived from a Revit model and synchronized by Maint3D. The sequence goes as follows, air sensor installed in Maint3D via QR code scan, then choosing the selected area in the Maint3D interface to connect the sensor's ID to room 052 GUID sensor ID as shown in figure 22 (Nguyen, 2016).

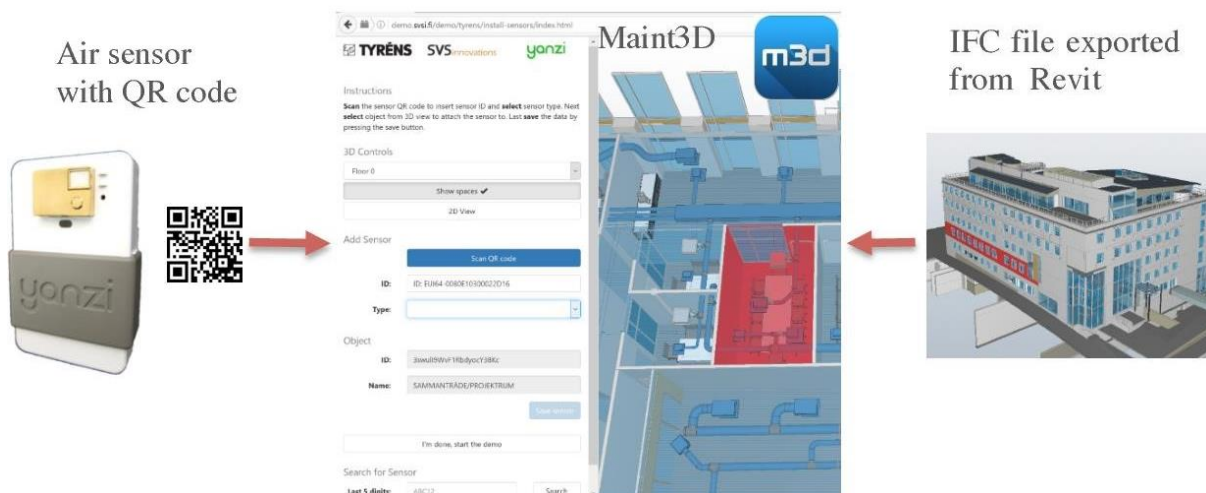


Figure 22: Sensor Instalment, BIM, and Maint3D overview. Reprinted from (Nguyen, 2016).

Room 052 lies in the center of floor 0 adjacent and joining interior walls with rooms 051, 053, and 86. In this layout, room 052 is trapped with no room for exterior walls or windows. Consequently, room 052 will experience fluctuations in neither CO₂ nor temperature levels compared to rooms 050 or 048. So, for more accurate measuring, the air sensor's ideal place is next to the air outlet where the exhaust airflow exists. However, for more accurate data, the air sensor must be as far as possible from the air inlet, vent of air conditioning, windows, and door (Nguyen, 2016).

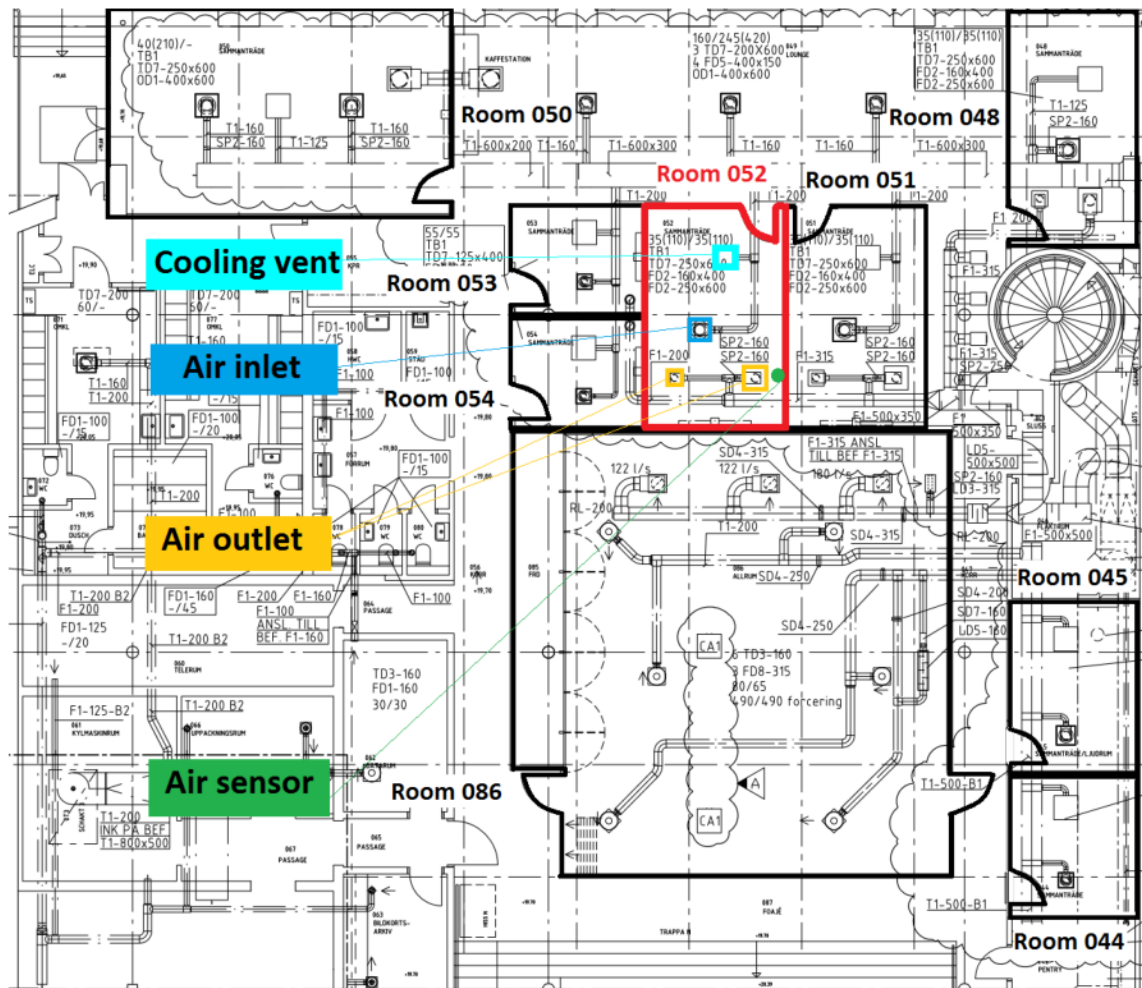


Figure 23: Air Sensor Positioning to Inlets, Exits, and Vents on the 0th-Floor Plan. Reprinted from (Nguyen, 2016).

5.3.3 Carbon Dioxide Concentration Level and Temperature Level

The ppm level was down to around 420ppm during the long lunch break; a standard air use level was equivalent to the CO₂ level for outdoor air. During lunch, the high

was at 848ppm, 15 minutes after returning. Throughout the afternoon meeting, it remained at a pace of 600-700ppm, which had little effect on thought or health. Meeting B was sampled in the second graph, this time with the door closed and 9 attendees. It began with outdoor-like quantities of about 420 ppm. Following the split, the above trend persists, but only 5-6 people have returned. The ppm has risen over 1000 ppm in 30 minutes. During this period, carbon dioxide levels are continuously rising and over 1500 ppm in the following hour – a continuous pace at 12.20 until lunch. Just 4 people came out, and the ppm was still over 1050 ppm at the baseline, with the door now locked (Nguyen, 2016). According to the recommended thresholds, a fixed point built into the device that ventilates fresh air as the base level approaches will make space user-friendly according to the user's expectations from the survey results.

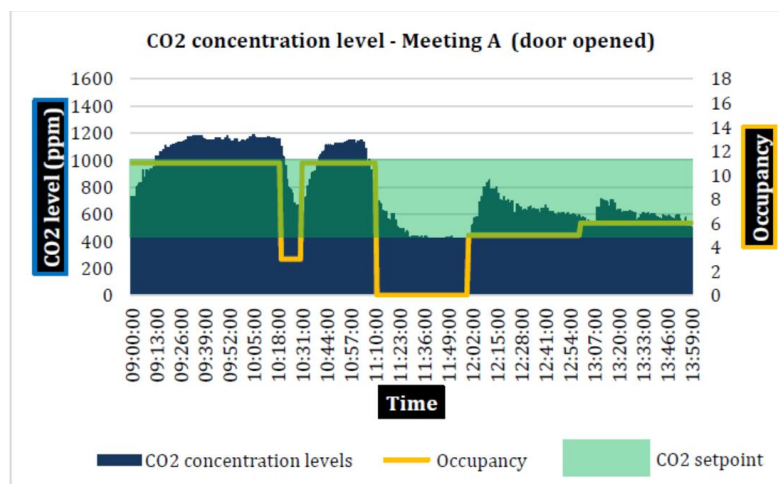


Figure 24: CO2 Concentration Level, Meeting A (Door Opened). Reprinted from (Nguyen, 2016)

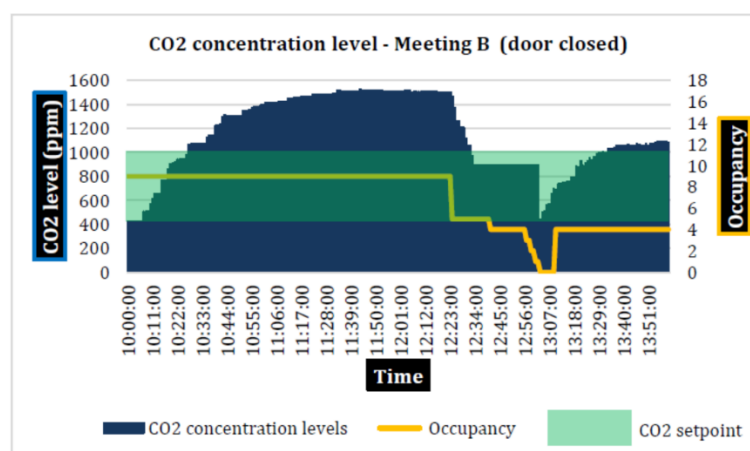


Figure 25: CO2 Concentration Level, Meeting B Door Closed). Reprinted from (Nguyen, 2016)

There was a linear and rapid rise to 23 C degrees in half an hour during the first meeting. It remained constant at 23 C despite the lunch break that did not help with the temperature level.

The rise is also linear in the second closed-door meeting B. Nevertheless, due to the smaller number of attendees, it was much slower this time. Closing the door keeps the current cooling fresh air flowing from the cooling vent in the room for a more extended period effectively, allowing it to cool the room's temperature down. Furthermore, the cooling vent is located very close to the entrance door. That means that when the door is opened, the cooling air from the cooling vent will easily escape into the corridor, potentially affecting the building's air circulation (Nguyen, 2016).

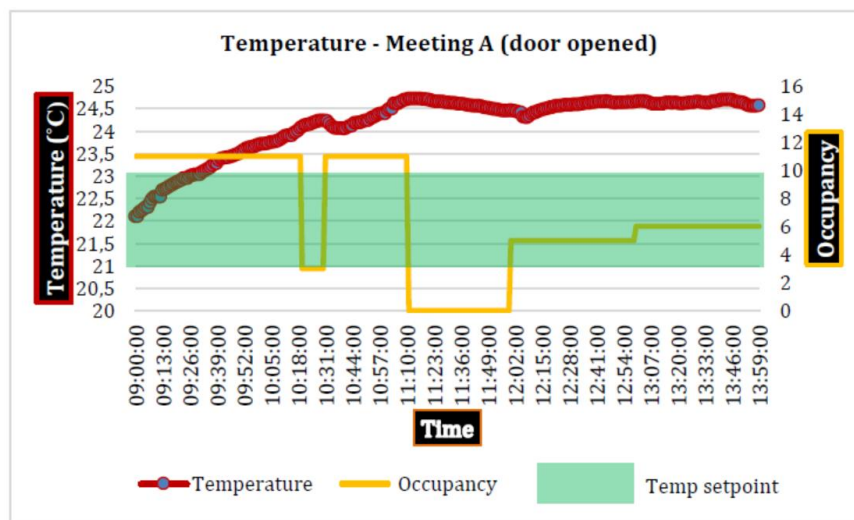


Figure 26: Meeting A Temperature Level (Door Opened). Reprinted from (Nguyen, 2016).

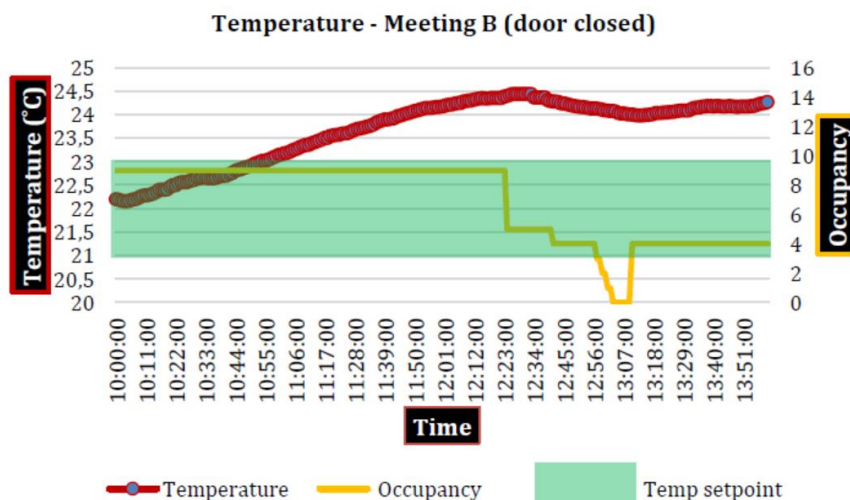


Figure 27: Meeting B Temperature Level (Door Closed). Reprinted from (Nguyen, 2016).

In summary, temperature increases cannot be seen as dramatic as the rise in the concentration of CO₂. Nevertheless, all these variables assessed in these extended meetings are at levels that could induce fatigue and declining mental functioning and decision-making to participants. Simultaneously, when participants got out of the room, CO₂ and temperature levels started increasing gradually until reaching the minimal limit after thirty minutes: 1000 ppm for CO₂ and 23°C degrees for temperature. The highest CO₂ levels reported were in meeting A (opened door) with 11 people and 1179 ppm. In comparison, meeting B (door closed) included 9 people with only 1516 ppm. As CO₂ concentrations have hit these thresholds, occupants' cognitive scores at meetings A and B may have fallen between 10% and 21%, respectively. In this sense, the cognitive value includes decision-making and the capacity to use knowledge (Allen et al., 2016).

These amounts were shown to continue steadily before marginally decreasing into the baseline following the number of inhabitants' decline. This suggests that if no fresh air was added into the room, this aspect would remain elevated, possibly creating more severe detrimental effects to the occupants. The Air sensor's collecting data also revealed an above-baseline temperature range in both meetings, with peak temperatures at 24.5 and 24.7 °C degrees, 1.5 and 1.7 °C degrees higher than the baseline. Prolonged meetings at these high temperatures can also have detrimental consequences for dynamic activities (Zhang & de Dear, 2016).

To incorporate the data of such sensors at lower CO₂ and temperature points to enable fresh air to enter the room more responsively, their employees' perceptions and other measurements of its operation may be of importance. In brief, the practical application of these sensors and data on the facility's monitoring and management systems will positively affect the perceived and other evaluated values' well-being and working ability—essential principles for various priorities human and corporate (Nguyen, 2016).

Accordingly, the temperature increases are not as extreme as the changes in CO₂ leading to the change inactivity. However, temperatures and CO₂ levels are at levels that might lead to pain, decreased cognitive capacity, and decision-making for people during these extended sessions. In this sense, the cognitive value includes decision-making and the capacity to use knowledge. These ratios were viewed as continuous until the mean decreased marginally after the number of people had decreased. In the

case of the lack of fresh air, it will remain at elevated temperatures, which would also cause the occupants more severe negative influences.

Moreover, The Air Sensor captured data also revealed over-the-counter temperature at the peaks at 24.5 and 24.7 °C degrees, 1.5 and 1.7 °C degrees, in both cases, more significant than the baseline degrees. Lengthy meetings during these high-temperature ranges may also have a detrimental impact on complicated tasks (Zhang & de Dear, 2016).

5.4 Discussion

Building systems such as HVAC, lighting, water temperature, and building equipment all contribute to Operational Energy (OE), which significantly impacts how FM and Life Cycle Energy affect CE. (Brown & Pitt, 2001, pp. 222-232). FM has a direct impact on building systems by determining maintenance and replacement actions. For example, the FM department may be called upon to make critical decisions such as upgrading or modifying systems in order to maximize a building's OE (Lavy & Dixit, 2012, pp. 80-98). By modernizing older technologies and increasing the operator's skill efficiency, facility managers can drastically minimize OE use (Jensen & Nielsen, 2008). Repairs can reduce the efficiency of building systems and machinery, resulting in significant energy and financial savings. For example, a traditional school in the United States used about 55% of its annual energy on HVAC and 30% lighting. This illustrates how site managers control approximately 85 percent of total annual energy consumption (Cash and Twiford, 2009). The majority of repair and replacement options necessitate extensive construction materials and methods such as installation, welding, and shipping. These same measures will improve a building's overall REE (Elmualim et al., 2010, pp.58-64) by recognizing and employing low-carbon electricity, durable materials, and components with shorter replacement times and minimal maintenance requirements on a local level (Lavy and Dixit, 2012). Using more recyclable materials and components is another way to shorten the REE construction life cycle. REE will dominate the overall LCEE of the building. Cole and Kernan (1996, pp. 307-317) show that the total REE can be more than three times the total Initial Embodied Energy (IEE) after 50 years, demonstrating the importance of FM. According to the estimates, by the end of 2030, building-related carbon emissions would have increased by 72 percent

from 2002 levels. As a result, CE from buildings is expected to increase by 72 percent by 2030, compared to 2002. However, by allowing FM to make environmentally beneficial options, most CE impacts may be controlled and reduced (Dixit et al., 2016).

The advancement and improvement in decision-making can be easily noted after the BIM integration at the design stage. This integration boosts the quality, speed, and availability of design data (Wong & Zhou, 2015, p. 163). Equally essential and practical, the BIM-LCA integration, as the first beta design, pushes designers and engineers to acquire solid results regarding the buildings' environmental performance. In the early stages of construction design, the proposed system will model the conclusions of the BLCCE. It can be used to measure the efficiency of frameworks and recommend alternatives that reduce carbon emissions.

In addition, the effective installation of these sensors and their data on the facility's control and steering systems may positively influence their perceived and other calculated values.

5.5 Concluding thoughts

After the industrial revolution, GHG has kept increasing dramatically. However, with the breakthrough in technology, science is trying to reduce GHG emissions. In this manner, BIM frameworks can be integrated and implemented to reduce operational GHG emissions using FM. Tyren building in Sweden is an excellent example of decreasing and monitoring GHG emissions and how environmental factors affect the quality of living and, subsequently, production. Therefore, implementing BIM models for more accurate sensing and maintaining the average or above-average levels of HVAC factors, temperature, and CO₂ levels, in particular, gives an overview of the importance of BIM-FM integration.

6. The Survey, Case Study

Sustainable design intervention is much more likely to be accepted if it considers how the stakeholders perceive and interpret high-performance buildings. This need to accommodate recipients' pre-existing concepts has been expressed in various areas, ranging from risk communication and strategic assessment to usability. In this context, the survey aims to expose the structure of participants' mental models about sustainable and improving facility management through integrating BIM and IoT.

There are several different conceptualizations of mental models in the literature, each advocating for a different method of accessing the material of such models. For the present research purposes, the definition of a mental model is operationalized as an internal, mental representation of external phenomena (Baird & Brier, 1981).

The Multiple choices technique is one tool for exposing internal representations of structures and concepts. The task requires the participant to select objects or concepts according to their relative importance/impact on a specific result, revealing the mechanisms of mental models by indicating how people interpret functional value between concepts. This methodology has long been employed in psychological research and, more recently, in usability, particularly in website design.

The survey conducted in the present research strategically uses the options methodology to answer questions like: What are the limitations of standard facility management? What benefits do the respondents think can be achieved from integrating facility management with BIM and IoT sensors? What has been/do the respondents expect to be the most significant benefit of installing smart technologies in your building? What do the respondents perceive as barriers regarding the adoption of BIM and IoT for FM? The researcher realizes that for most of these questions, the answer is mainly dependent on the uniqueness of each project. However, this survey experiment aims not to quantify facility management's impacts on operational energy use (kw.h/m²). Instead, the survey is designed to provide an insight into in current mindset (i.e., mental models) regarding the appropriate use of FM throughout the design and operational stages of a given project to enhance its performance. The goal is to identify prime deficiencies in the marketplace and contextual barriers against

formulating/implementing an Agile design framework, ultimately defining the gap between industry mindsets and current design practices.

The survey collected a total of (88) survey responses: 71 participants completed all questions of the survey, and 17 skipped some questions on the survey

Nonetheless, the survey resulted in significant discrepancies between the three focus groups, with 42.31% is related to real estate developers, 25.64% is related to facility managers, and 15.38 % architects. However, it seems that both contractors and construction management /engineering have scored similarly 5.13% while 3.85% in other were BIM Managers, as shown in figure 28. Indeed, recruiting an equal number of participants in all focus groups would have yielded a comparable set of data connecting facility managers' vision. However, understanding that gathering comprehensive data typically results in entirely unpredictable challenges at the start of a project, the researcher opted to be responsive to the practical realities of results. Thus, this chapter does not attempt to statistically compare survey responses between participant groups (e.g., facility managers vs. real estate developers). They both have different roles that require different skills and responsibilities. Instead, this chapter investigates and critically evaluates BIM and IoT as an FM tool to augment and add value to building operation, maintenance, and decision-making.

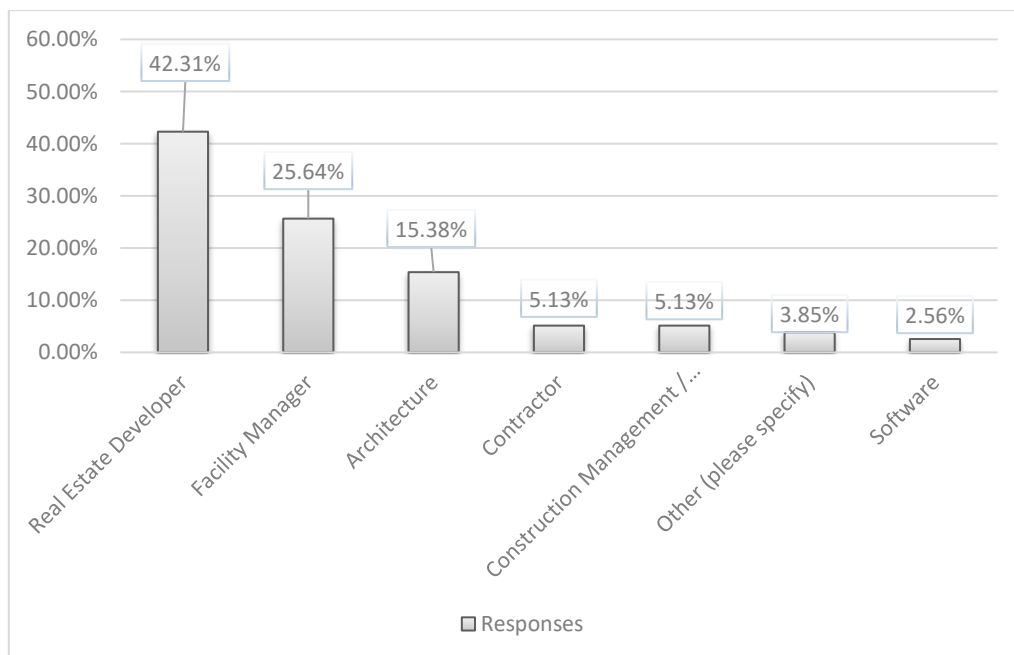


Figure 28: Respondents' Role in Their Companies

6 .1 Survey Design:

An online questionnaire was conducted to capture insights into current mindsets and practices regarding the integration of BIM and IoT in Facility Management. The nature of questions concerns designers' approaches to facility management integrations with new technologies. The survey was distributed and administrated digitally via Survey Monkey web-based platform, and answers are completely randomized. The questionnaire is structured using a pre-determined set of closed-ended. At the same time, select questions have an open-dialogue option for comments, Multiple choice, and agree and disagree, as this is felt to be the most appropriate for the sample groups. However, almost 95% of participants ignored the comments window and opted only to answer the scaled questions (multiple choices). As highlighted earlier, the questionnaire aims to obtain views about the effectiveness of using BIM and IoT sensor strategies for existing and new buildings to enhance facility management.

Respondents were redirected to an information page, figure 29, a snapshot of the survey monkey, after clicking the link within the invitation message or article. This page identified the researcher's association and included a brief description of the survey's objectives, which were presented as an investigation into facilities management versatility.



Developing a BIM based framework for Sustainable Facility Management

Thank you for participating in our survey. Your feedback is important.

The purpose of this research project is developing a BIM based framework for Sustainable Facility Management by integration BIM and IOT sensors . The forthcoming theoretical frame is viewed as a medium to aid facility managers and policymakers - and by implication incorporated in the decision-making process - in seeking and realizing greater FM flexibility, as to improve the ability of buildings to adjust for changing circumstances and technologies without excessive waste and conflict.

The present research defines facility management (FM) as "managing the building performance by integrating people, place, process, and technology to ensure the efficiency of the buildings environment." FM aims to provide the ultimate interaction and integration between human intellect and technological efficiency, as well as accuracy.

If you require more details, please do not hesitate to ask.

Researcher: Ahmed Aziz, Master's Student at Hochschule für Technik und Wirtschaft (HTW) Berlin.

ahmed.aziz@student.htw-berlin.de | www.htw-berlin.de

ahmed.aziz@metropolia.fi

Figure 29: General Information Snapshot from "Survey Monkey."

The survey's objectives—along with the case studies approach—are to benefits and challenges of BIM-IoT in facility management combination and identify the industry perception regarding the environmental, social, and economic tenets of sustainable development. The following few pages in this chapter present a comprehensive description of the survey design, methods, and results.

6.2 Survey Method and population

6.2.1 Method:

The present research adopts a non-probability sampling method, namely, purposive sampling, where each potential subject has a known tendency to be chosen for the questionnaire (Robinson, 2013). The category that is deliberately included in the sample is real estate developers, facility managers, and architects (all of whom are deemed knowledgeable in facility management). Participants' selection method within the purposive category is judgment sampling (Robinson, 2013), following a non-random sample selected based on a pre-identified set of requirements. This technique guarantees that central populations are included in the survey using minimum quotas, thus preventing bias collection or inference. This method is widely used in applied qualitative analysis, such as market research and consumer behavior. (Uprichard, 2013). Table 9 contextualizes the sampling method used and defines each method in the milieu of the survey undertaken in the present research. Additionally, the following pages elucidate the pre-identified requirements that define the target population as “experts,” as well as the sample size and recruitment journey.

The data collected below are discussed in the context highlighted in figure 30. This inquiry aims to validate the research hypothesis of the industry's need for a theoretical framework for setting such flexibility concepts.

Table 9: Survey Sampling Methods Towards Recruiting Experts in the field of Facility Management.

Sampling methods	Definitions	
Non-probability method → Purposive sampling → Structured questionnaire → Administrated digitally	Nonprobability method	Individuals in a non-probability survey are chosen using non-random parameters, and not every individual has a chance of being included (McCombes, 2019). In the present research, the non-random sampling criteria consist of a pre-identified set of requirements
	Purposive sampling	The study uses this sort of sampling to pick a sample within the population that is most helpful in the study (McCombes, 2019) using its assessment (specific characteristics). Purpose sampling is also used to obtain a holistic understanding of a particular phenomenon in a qualitative study. To establish an adequate purposive sample, the present survey study established a clear criterion
	Structured questionnaire	It consists of a set of primarily close-ended questions with a standardized scheme, which specifies the wording and order of the questions for gathering information or understand behavior from respondents (Cheung & Jim, 2013).

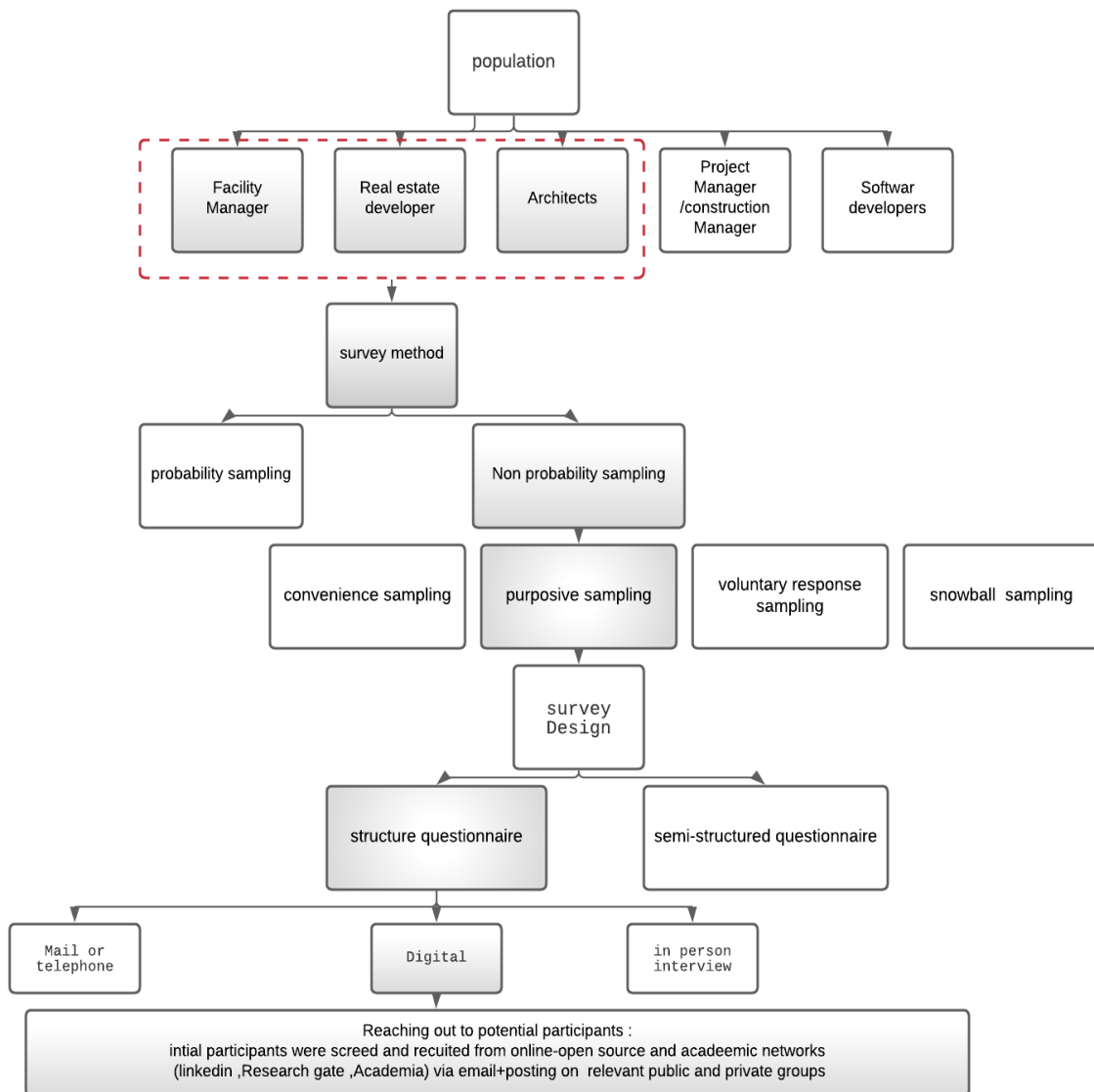


Figure 30: Survey Design and Methods Diagram.

6.3 Target Population: Who are The Target Experts?

The survey's target population is designed to assess how experts -in the engineering industry- perceive facility management concepts and philosophies. The ideologies presented by a group of professionals with specialized knowledge of sustainability principles are perceived as insightful regarding the research efforts to recognize current industry mindsets (i.e., mental models) regarding the sustainable building design process. The research defines the target experts employing pre-identified criteria

described in table 10. The rationale behind each criterion is a judgment attempt to filter participants by their level of experience or achievement related to facility management. Additionally, priority levels were added as means to pre-define the minimum sample requirements (MSR) as mandatory. Total valid responses (meets the pre-identified criteria) are 66 participants.

Table 10: Pre-identified Criteria to Recruit the Target Population

Target group	Pre-identified criteria	
	Requirements	Priority
Real estate developers	Minimum of 6 years of industry experience.	Mandatory
	Minimum of 8 years of industry experience	Desirable
	Involved in the design process of a range of national and international projects that promotes facility management	Mandatory
Facility Manager	Minimum 10 years of industry experience.	Mandatory
	A firm scale of more than 1000 employees	Optional
Architects	Minimum of 3 years of experience	Mandatory
	Involved in the design process of a range of national and international projects that promotes facility management	Optional

6.3.1 Data and Analysis

The survey, part 1 questions, profile phase, mainly understood if the participant met the pre-identified criteria highlighted in Table 10. Thus, to identify whether that response qualifies as valid in the context of this research and then guide the participants by applying logic features in survey monkey. In part 2, benefits and challenges, the researcher designed these questions for participants with experience in facility management to identify industry limitations and best practices. The survey flow (designed using survey Monkey software) takes participants through 3-step-journey: the profile, benefits, and challenges, and added value as they navigate through the questionnaire. As participants describe/select their role in the AEC industry, they are directed to a validation stage. The questionnaire collects screening data concerning the pre-identified requirements to recruit the target population. Then, participants move to the next step of the flow, which is the main body of the questionnaire. The weighted average method was used to evaluate figures 36-38. By multiplying each ranking by the corresponding rating score (e.g., 1-5), a weighted average is estimated and then adds the outcomes of these estimates to the total number of questions after the division

6.4 Survey Result

6.4.1 Participants Profile

A total of 88 participants accessed the online questionnaire, with 17 incomplete responses and 5 participants failing to pass the pre-identified criteria highlighted in table 10 to filter experts in sustainable building design and facility management. Table 11 breaks down the total valid survey responses. The target population was recruited through online open-source professional and academic networks, i.e., LinkedIn, Academia, and Research Gate. Individuals were invited to participate in an online survey of issues concerning “facility management, flexibility, and integrated facility management.” An invitation email or post was circulated via direct contact, e.g., LinkedIn or Academia messages, or posting on relevant LinkedIn groups with at least 1000 members to approach active and up-to-date audiences like International Facility Management Association, Integrated Facility Management, Property and Facility Management Innovators (PFMI), MM - Maintenance and Facility Management, Etc. The invitation message included a brief description of the project and a link to an online questionnaire that participants could access from their computer or mobile phone. The survey is randomized, and therefore it is in no way possible to identify which post or message had a higher conversion rate. Also, questionnaire results are anonymous, meaning there are no personal identifying questions related to respondents’ names, companies, research institutes, or even country of residence. The questionnaire starts with a validation stage, at which participants are their role in the AEC industry. According to their answer, participants are directed to an exclusive set of questions corresponding to the pre-identified criteria. For example, if a participant defines his role, the next question would be how many years of experience they have in the AEC industry and then the professional background within the firm affiliated with the respondents’ scale.

Table 11: Total Valid Survey Responses.

	Total
Total survey responses (from all target groups)	88
Incomplete survey response (skipped)	17
Total complete response	71
Total valid responses (meets the pre-identified criteria)	66

According to the survey results, 44.87 % of respondents had more than 10 years of experience in the AEC sector, while 34.86 % had 6 to 10 years of experience. 20.51% have less than 6 years of experience. This indicates that the responders with more experience have participated in the survey.

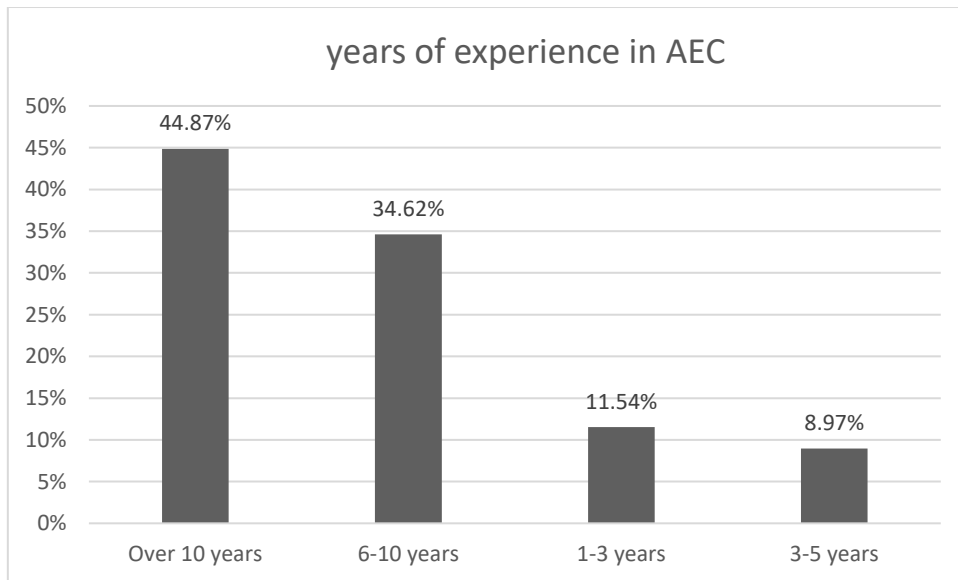


Figure 31: Years of Expertise of Participants in the AEC Industry.

Figure 32 indicates that 38.64 % of operational FM-based projects are using this mechanism for all the projects, few projects 35.9%, and 25.64% have either never used or not sure has used or not.

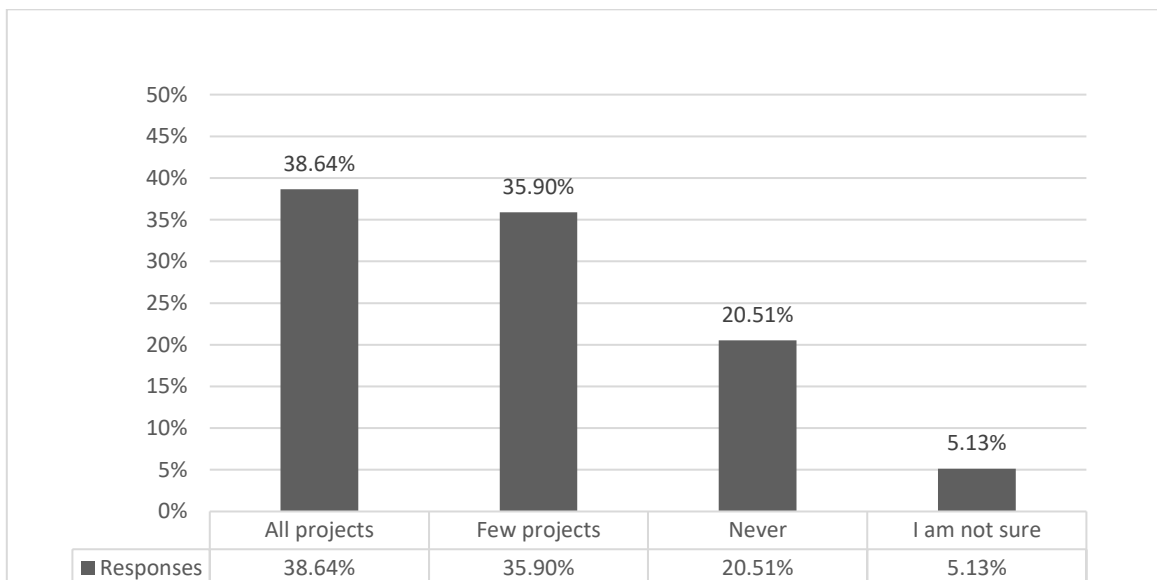


Figure 32: Plan Early to Account for Operational Facility Management

Figure 33 illustrates that 31% use facility management to manage commercial/retail buildings, 20% manage educational buildings, offices, and residential are nearly similar which offices targeted 18%, and residential 17%. The survey indicates that 10% is related to industrial while 5% present infrastructure.

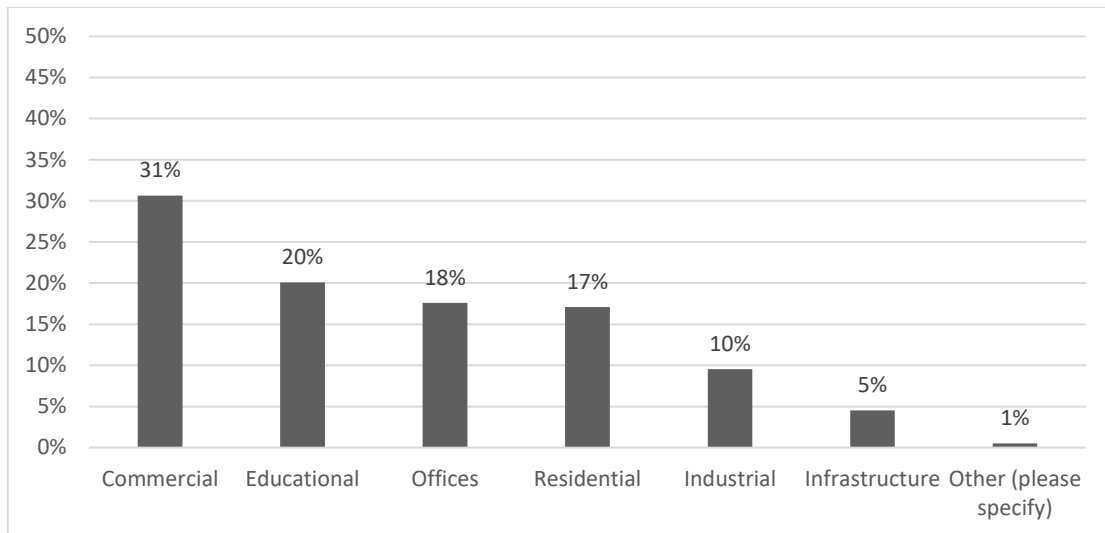


Figure 33: What Categories Best Describe the Buildings/Facilities Managed

Survey participants were in global cities in Europe, Africa, North America, etc. The majority were from the EU, 36.9%, followed by Africa 19.8% and the least 14.86% from Asia, and finally, 12.33% in North America. According to survey respondents, figure 34 shows that the majority who use FM are space, energy, and contract management, while the least are the environmental management, security, and room scheduling management.

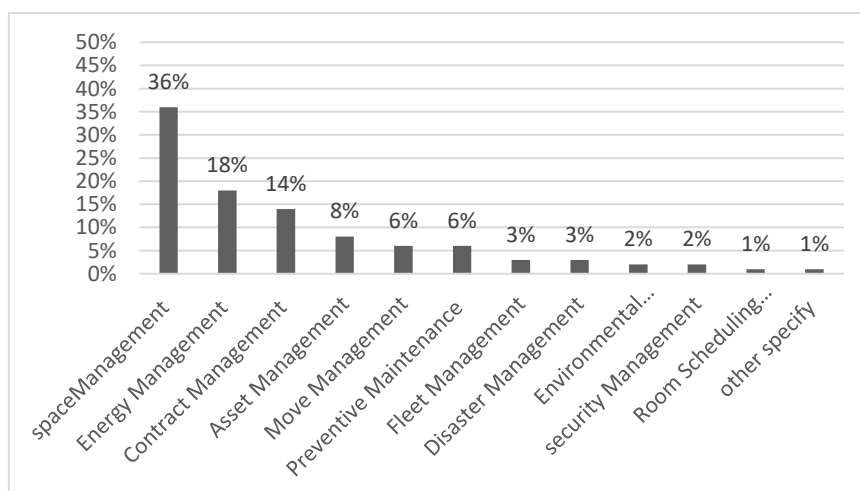


Figure 34: What Activities Do You Use Your Facility Management Software For? (Select All That Apply)

Whether it is conference rooms, storage, laboratories, desks, or dining space, a company will make every inch of their space work for them. Space management software offers the reliable and real-time data required to determine if spaces should be used more efficiently. This ensures that businesses can repurpose spaces that are not being used effectively or even make a case for new ones. This means that businesses can repurpose spaces that are not being used for the right reasons or even make a case for or against expansion based on real-time data. A company with a space team with access to real-time, reliable data will make better decisions, lowering portfolio costs dramatically to cut prices effectively.

The focus of space management is moving away from lowering space costs and building a working atmosphere that attracts and retains top talent. This is not to say that cutting space costs is not always a top priority for facility and space managers. However, finding the right balance is becoming increasingly necessary to build a friendly working atmosphere and increase productivity, so the current study is so important. In participants' responses, only 2% voted for the significance of environmental management, which includes embodied carbon emission, materials durability, and water management. In this manner, the limited literacy regarding what is often quoted as the "blind spot" of buildings' carbon emissions. In its simplest form, environmental management can be defined as a methodical approach to identifying realistic ways to save water, electricity, and materials while reducing adverse environmental effects

Therefore, the framework introduced in the present research advocates for energy management to include early-stage planning for operation energy production and energy consumption units as energy distribution and storage. The framework suggests a systemic effort to maximize energy production for overall political, fiscal, and environmental goals through engineering and management.

The survey participants indicate that 22.22% use CMMS Software, 19.44% use different BIM software, 15.28% use CAFM, 13.89% depend on CAD, while only 6.94% depending on IWMS. Worth noting that 9.73% use none of the mentioned software or other like NETSUITE software. As per the survey result, a computerized maintenance management system most familiar in practice, CMMS Software, centralizes maintenance data and streamlines maintenance processes. It aids in the efficient and

effective use of physical assets such as vehicles, machinery, communications, plant infrastructures, and other assets.

CMMS is flexible, simple to use, and enables organizations to customize it to meet their specific requirements. For example, make obligatory fields that a technician must fill out before closing a work order. On the other hand, building information modeling software is highly recommended, compelling new tools that allow facility managers to enhance building performance and manage the operation BIM program more than just a 3D computer-generated model of the structure.

In a nutshell, CAFM aids facility managers (FM) automate various aspects of facility management, including real estate utilization. On the other hand, CMMS software is primarily included in the CAFM kit and includes tools for managing maintenance operations. This means that CAFM helps facility managers automate numerous areas of facility management, including real estate, and allows them to execute and plan all activities such as planned preventive maintenance, asset management, space management, and other customer services. CAFM includes computer integrated facility management, but it concentrates on emergency and critical safety, which requires integration with a particular type of sensor; most firefighting organizations choose this type because it detects fires quickly. NetSuite oracle program integrated AP automation system, which controls inventories and records financials, easy plate form, and easy to understand and essential for e-commerce companies, is used by 4.17 percent of participants

6.4.2 Benefits and challenges

Implementing BIM in building management relies on receiving pertinent knowledge from BIM to execute significant activities; however, this does not mean that such integration is a straightforward process. Several challenges must first be addressed, including ensuring the interoperability of the data and applications used in all sectors, adapting the BIM paradigm to the demands of its administrators, and the cultural shift required to introduce a modern building management technology.

The limitation of the current use of facility management shown in figure 35 that 41.43% indicates significantly poor data interoperability while 25.71% were neutral, and 30%

finds it very significant. On the other hand, 44.29% find poor data accessibility significant, 27.14% find it very significant, and 22.86% find it neutral. In addition to the lack of location-based/ geographic functionality, 44.29% find it significant, 38.57% find it neutral, and 7.14% find it very insignificant. Further, 44.93% find the lack of data significant, 42.03% find it neutral, and 7.25% find it very significant. Finally, 40% find inadequate data transference and exchange significant, 34.29% find it neutral, and 18.57% find it very significant.

Indeed, the compatibility of BIM and FM technologies is minimal. This is challenging because the life cycle of BIM technologies and FM technologies is substantially different. Undoubtedly, CAFM and other asset management systems include structured data libraries and open systems. Systems that have long been used for FM purposes, e.g., CMMS, CAFM, EMS BAS, or EDMS, have been proved helpful in operation. However, lacking interoperability is defined by the flexibility that dramatically restricts their capability. They operate smoothly as independent programs, but they cannot connect, and no information-sharing network is available. As a result, time spent on FM actions and incorporating key details, resulting in financial losses, are inefficient.

An intensive volume of data to be captured and maintained throughout the facility's life cycle is one of the most critical impediments in the FM industry. BIM will help facility administrators access data more quickly and easily. BIM is something that Facilities Management must communicate with, and that collaboration must begin as quickly as practical. The format of data sharing plays a crucial role in this regard. The critical problems for facilities administrators remain data accuracy and integration between facility management and BIM software applications. BIM interpretation information management should contribute to the Integrated Project Delivery (IPD) definition, which focuses on distributing multi-dimensional BIM-model information to all investment process members. The IPD builds on collaborative expertise and technologies favoring both investor and construction partners' open and native data formats. The open IFC format built by building smart is becoming increasingly common in architecture and construction. COBIE, a spreadsheet data format with several add-in programs, such as COBIE Toolkit for Revit, is another approach intended to facilitate data sharing between BIM models and data sets used in FM. However, the methods do have a range of shortcomings along with the capability for data mining.

The current study established the following problems associated with FM development: interoperability and improved data integration, enhanced information management, and enhanced preparation and skill development for facility managers. In terms of emerging technological advancement, the introduction of BIM and BEMS A Building Energy Management System for more intuitive and productive facilities management is a required field.

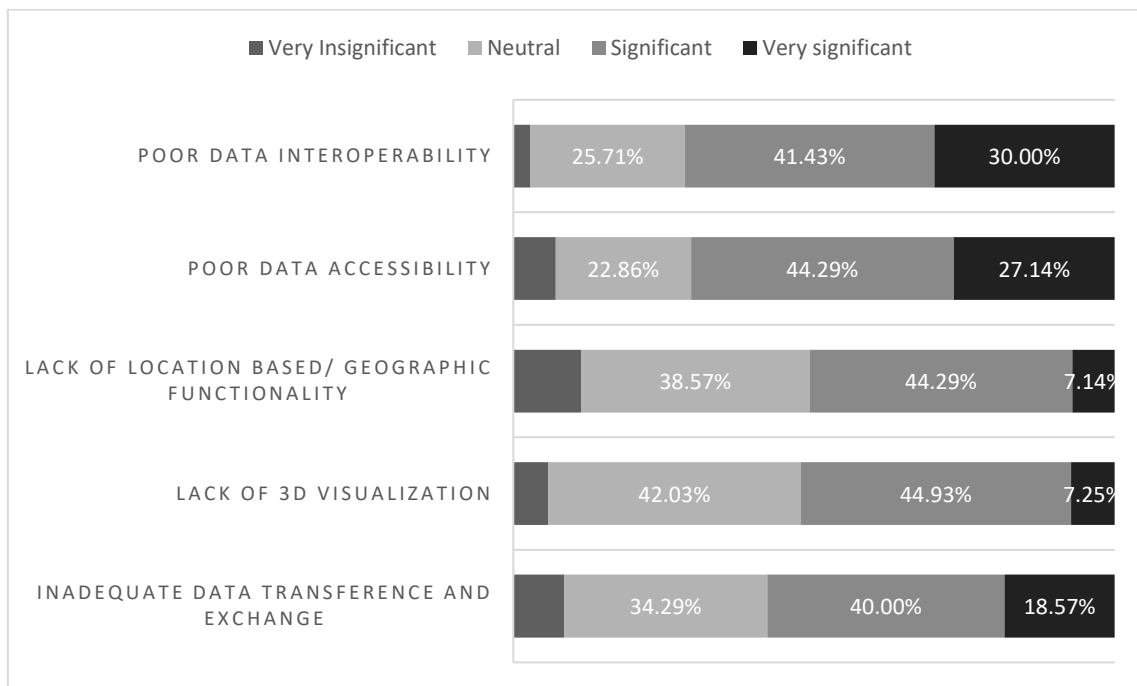


Figure 35: What Are The Limitations (if any) of Standards Facility Management?

As shown in figure 36, the Benefits of integrating FM with BIM and IoT, 3.49 weighted average results by descending sequence due to customer satisfaction, 3.43 strategic management, while 3.4 indicates efficiency, 3.32 indicates cost reduction, and 3.29% indicates decision-making.

The concept outlined in this study highlights building sustainability, infrastructure, and facilities activities together with BIM and IoT. BIM enables FMs to make strategic choices on land usage, floor design, infrastructure and asset management, energy use, and cost efficiencies over the facility's entire lifecycle. Data Analytics capabilities with the data gathered provide facilities managers and their clients with insight into how people use this building, maximize sustainability, reduce operating costs, and generate the best user and consumer experience possible. Strategic management is a

perspective to increase the efficiency of the building by collaborating with all partners to prevent job overlap and errors.

Each request to be met by a facilities manager has a related expense. Equipment such as workers hiring, repairing, and servicing, inventory and supply, surveillance, and security is not easy to access or affordable. Cost accounting is one of the most challenging tasks a service manager needs to face in simplified terms. The standard of the service offered must be balanced and made into the budget. BIM can help organizations remove waste from their operations, and they can install the plant as much as they need to develop the ideal model. Which also offers quality assurance. BIM enables more informed decision-making, transparency, enhanced connectivity, and, in general, better market results.

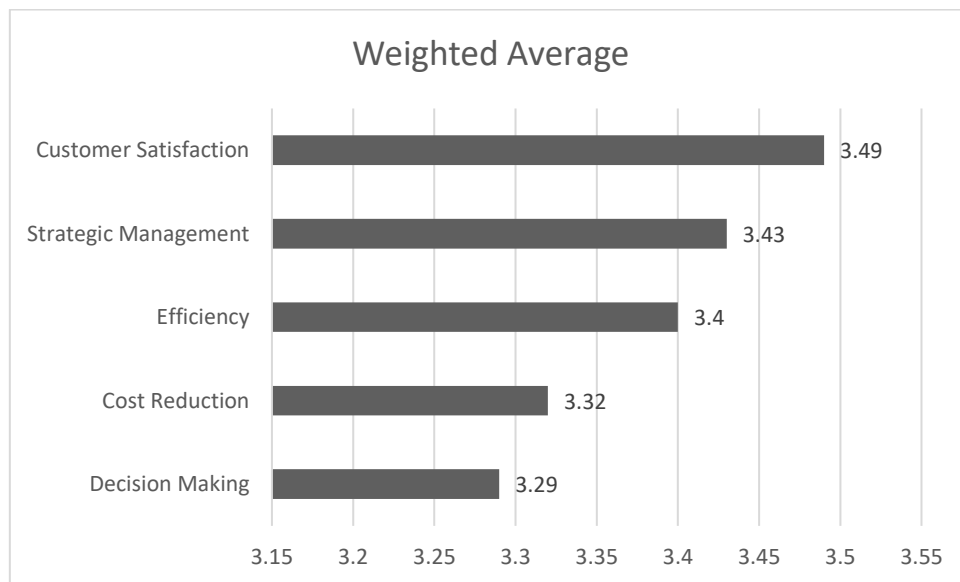


Figure 36: Benefits of integrating FM with BIM and IoT.

Building information modeling (BIM) encourages building research, especially in sustainability initiatives. Figure 37 shows that 3.43% weighted average believe that sustainability and energy management are the primary uses of BIM for facility management, while 3.41% see space management as the second use. 3.32% indicate asset management, 3.23 indicate 3D visualization, and 3.16% indicate database and data management. Furthermore, BIM can compare different energy options to reduce environmental impacts and operational costs significantly.

BIM improves space management through visualization; when space requirements or purposes change, BIM assists in identifying conflicts

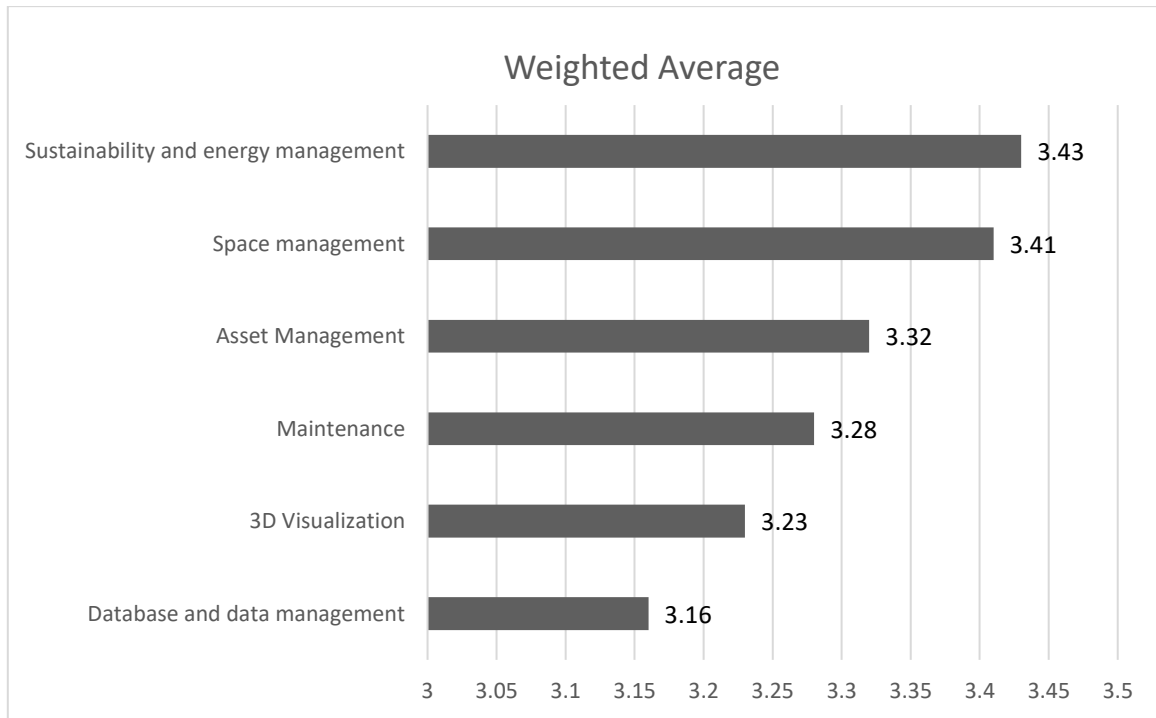


Figure 37: What Do You Consider the Uses of BIM to be for Facility Management?

Figure 38 shows below that 3.38% indicate the lack of BIM& IOT knowledge amongst building owners and operators is the main barrier, 3.09% indicate cost/budget, and 2.39% BIM & IoT tools are not designed to support facility management.

BIM and IoT are not well-understood by owners and a lot of facility managers. They are unsure how BIM and IoT can be applied to FM. There is a complete lack of best practice case studies and hard evidence to demonstrate the advantages of BIM and IoT in the FM industry. There is a lack of existing case studies and scientific research. Facility managers and real estate developers need accurate documents and evidence to promote BIM and IoT to owners. Another barrier to adoption is the lack of acceptance for BIM and IoT for FM cost reduction.

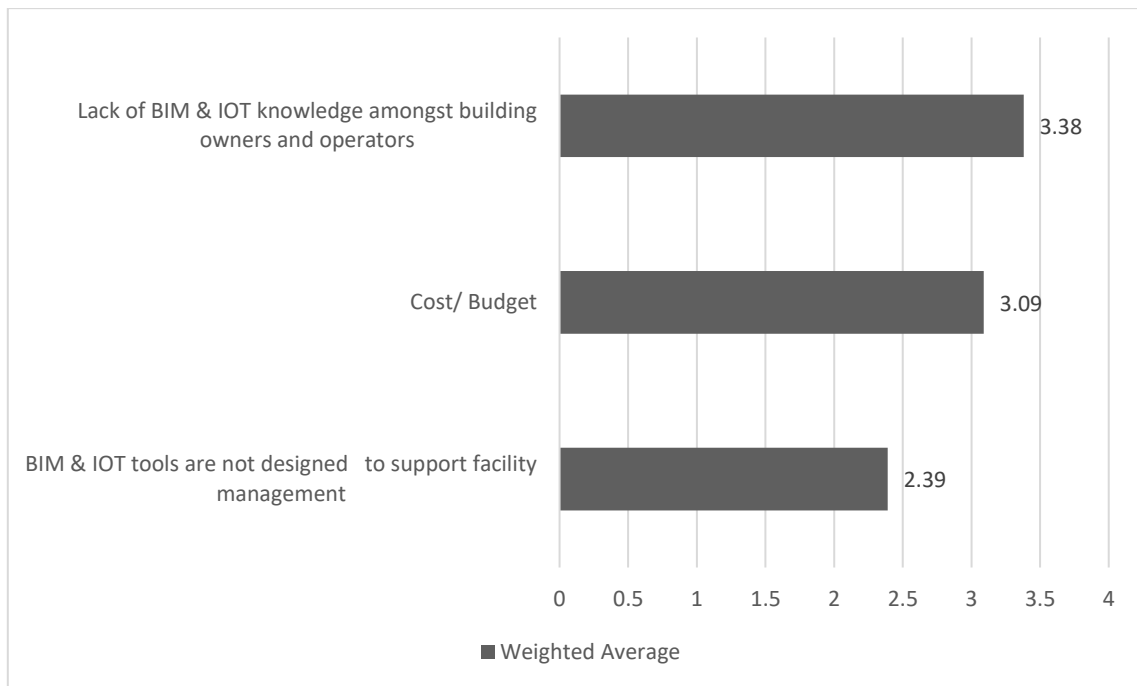


Figure 38: What Do You Perceive as Barriers Regarding the Adoption of BIM and IoT for FM?

Figure 39 below illustrates that 35% indicate that the basic knowledge of BIM and its irrationality to their organization is challenging to implement BIM and IoT in their workplace. The proceeding issue is the management commitment with 23%, 12% goes to management commitment and training, and support, with an equal 10% goes to financial issues and BIM guidelines and specifications. 5% indicates hardware and software costs, and finally, with equal 3% goes to IT security issues and BIM contracts.

The competencies are designed to improve the company's present BIM and IoT understanding. It is primarily directed at the employees who work in the execution divisions. The lack of measurements for BIM use was a severe challenge at the project level. Individual project evaluation tools for BIM implementation are available. However, due to a lack of resources, they are too expensive to use throughout the organization. As a result, including measurements into the existing assessment process would be the best method. The metrics that were used could be applied to other regions that have been studied.

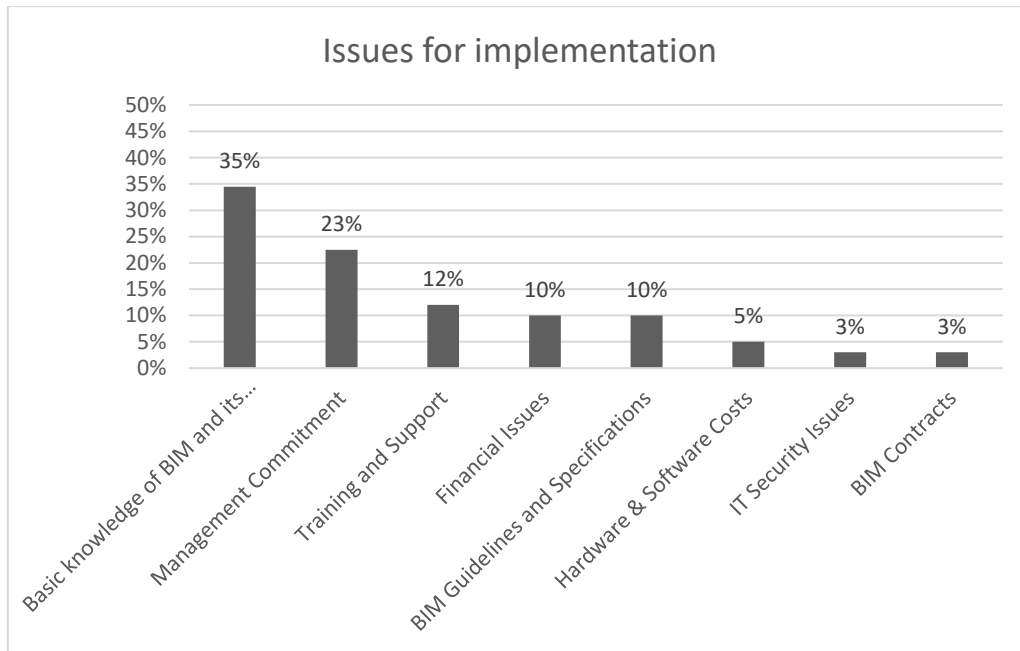


Figure 39: Issues That Organizations Face in Trying to Understand or Implement BIM and IoT in the Workplace.

Figure 40 below indicate that 28% use of BIM would reduce the cost of charging occupancy and configuration, 27% indicate creating a more comfortable environment for staff and customers, 18% indicate improving security, 15% indicate helping staff doing their jobs more efficiently, and 12% indicate cutting energy costs usage/costs. The integration between BIM and IoT offers vast potentials for fundamentally altering the ways by maintaining operating facilities.

BIM allows facility managers to access facility information in minutes, whereas obtaining the same information without BIM could take hours of work. FM departments use BIM technology to minimize operations and maintenance costs, improve control system appropriateness, and continuously provide cost-effective services to facility occupants. The goal of facility management is to perform cost-effective service. The goal of facility management is to reduce operating costs, increase energy efficiency, promote sustainability, and improve facility quality.

An IoT and analytical device-enabled building avoid unsuitable modifications such as unwanted access to the facilities management system. Third-party facilities management firms are successfully utilizing the potential of IoT and analytics to address cybersecurity and physical security risks. In other words, IoT and analytics

help businesses to maintain better control over their environments while still granting authentic inhabitants user access.

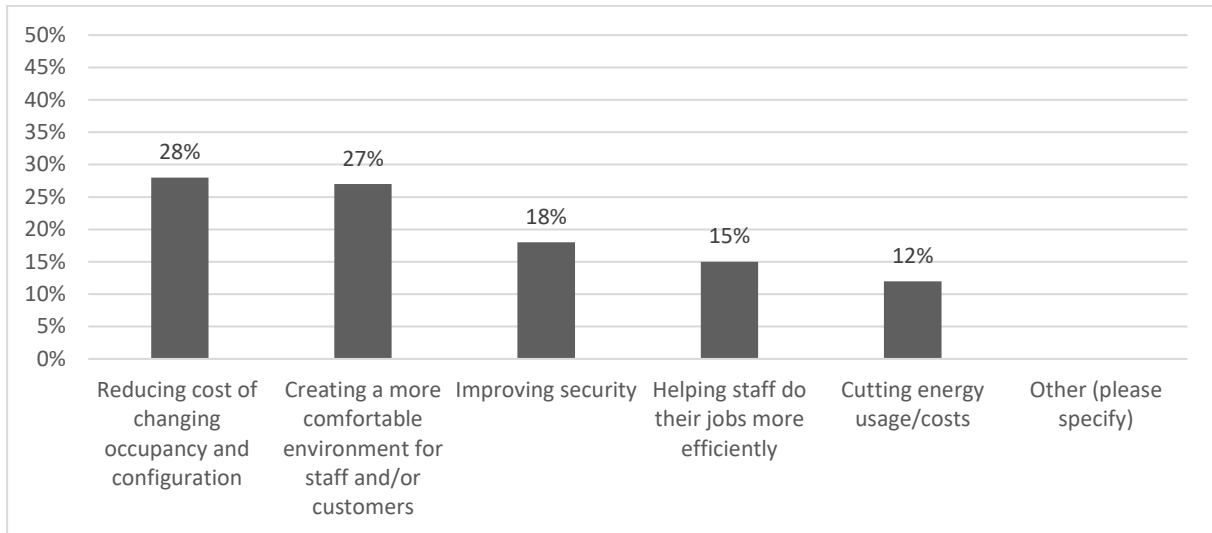


Figure 40: What Has Been Expected the Biggest Benefits of Installing Smart Technologies in Buildings?

As figure 41 analyses reached that 27% indicate by rating that emergencies are the top item that causes work orders, 25% indicate that power quality and reliability is the second item, 20% indicate that indoor air quality is the third item, 12% indicate that furniture and equipment repair is the fourth item. In comparison, 7% indicate that lightning issues are the fifth item, proceeded by heavy floor loading, moves/charges, and weather impacts are the last three items in the list with 5%, 3%, 1%, respectively.

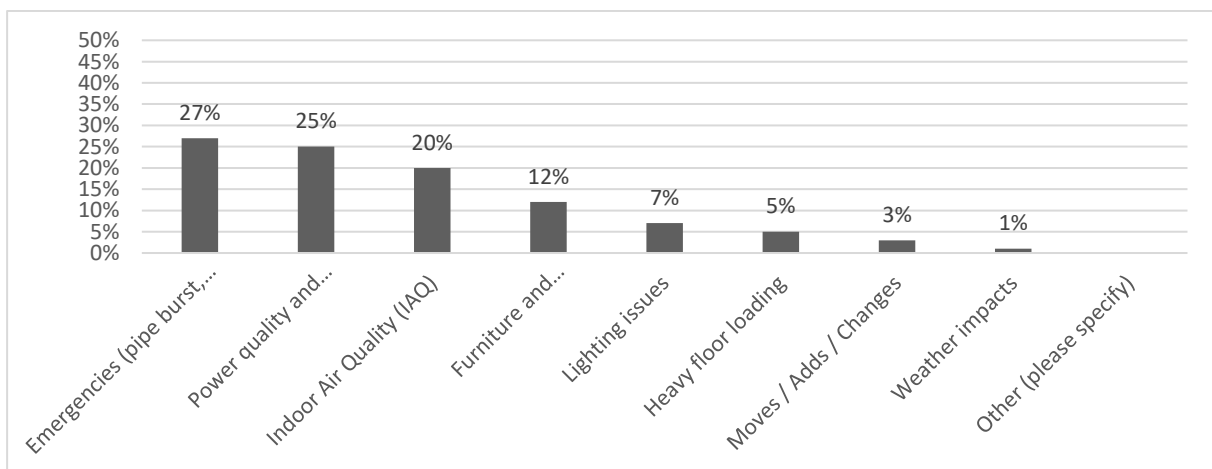


Figure 41: Most Maintenance Work Orders

Traditional manual work order management is ineffective, time-consuming, and leaves too much room for error. A more innovative approach to work order management is to digitalize and automate processes where possible. This can be achieved through BIM and IoT integration.

Most CMMS applications take a long time to import the data from construction site documentation into the CMMS to use daily facility Operations & Maintenance (O&M). Furthermore, many owners cannot begin with a fully developed BIM from a construction model. Via BIM and IoT and through CAFM as affordable solutions automatically make work orders, which helps facility managers prioritize the work orders and monitor them. For instance, scheduling maintenance and repairs lead to a more productive and comfortable working environment, with automatic creation and assignment to the relevant department based on urgency.

Figure 42 shows below the added value by integration BIM and IoT in FM, which indicates 44.93% strongly agree on using BIM and IoT in facilities management to enable facility managers to manage and optimize maintenance services effectively, 34.78% agree, and 10.14% neutral agree. 46.38% agree that BIM implementation costs outweigh the financial gains of BIM and IoT sensors for FM, 27.54% strongly agree, and 15.94% neutral agree. 43.28% agree that BIM will improve facilities management processes and productivity, 38.81% agree, and 10.45% neutral agree, 57.55% agree that BIM and IoT use in facilities management should be considered the future effectively managed facilities, 25% strongly agree, and 10.29% neutral agree.

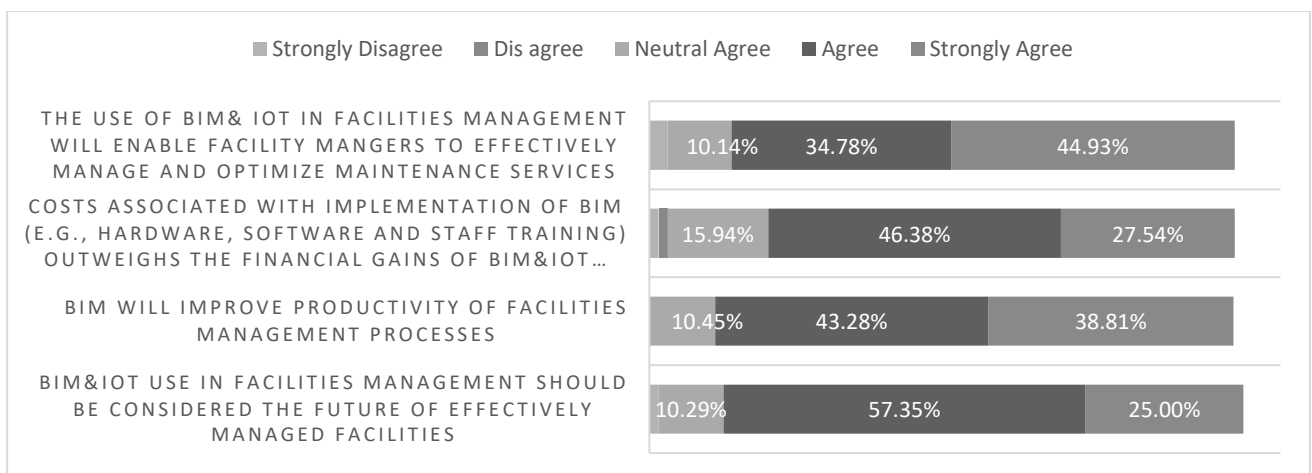


Figure 42: Added Value by Integration BIM and IoT in Facility Management

6.5 Concluding Thoughts

The survey was conducted to understand the current mindsets and practices of the BIM-IoT integration in facility management; and how the concerned target group perceives facility management concepts and philosophies. The survey shows that most of the participants are experienced, with 36.9% of them use FM in the EU with a particular focus on space, energy, and contract management. However, as mentioned earlier, BIM-IoT integration in FM is relatively new and is not used much. As seen in the survey, the highest group willing to take the risk of trying something new uses this integration in commercial/retail buildings. On the other hand, the survey highlights the importance of finding the right balance to build a friendly working atmosphere and increase productivity with minimal costs. The stakeholders entitled to using BIM in FM believe that suitability and energy are the principal uses for FM, followed by FM in space management and asset management. To boot, participants see the BIM capability to significantly compare different energy options to reduce environmental impacts and operational costs. In this manner, data analytics capabilities with the data gathered provide facilities managers and clients with insight into how people use this building, maximize sustainability, reduce operating costs, and generate the best user and consumer experience possible despite the minimal compatibility of BIM and FM technologies. For instance, An IoT and analytical device-enabled building avoid unsuitable modifications such as unwanted access to the facilities management system or CE reduction. This leads to the successful utilization of IoT and analytics targeting cybersecurity and physical security risks.

To put it another way, IoT and analytics help businesses to maintain better control over their environments while still granting authentic inhabitants user access, thus, maintaining sustainability, especially over emergencies. On the other hand, the survey showed that BIM and IoT knowledge, cost/budget, and the lack of BIM and IoT designing tools supporting FM are the main barriers to efficiently implementing BIM-IoT integration and proving efficiency in FM resulting in the lack of best practice case studies and hard evidence to demonstrate the advantages of BIM and IoT in the FM industry.

7. Results and conclusions

7.1 Discussions and Key Findings

BIM is a developing technology in the FM application. During the planning, design, and building processes, the prior BIM implementations were thoroughly reviewed and examined. In these initial stages, it is essential to understand the difficulties and value-added potential of BIM in FM. A review and survey (questionnaire case study) in this research have been applied to exploring these topics.

Having proved the usefulness of BIM in FM, the previously exhibited scenarios showed discussion of the obstacles of transitioning from present FM procedures to BIM-based processes with the FM estate department. Multiple issues have been observed in the deployment. The applied examples of BIM and FM implementation have verified and proved the advantages of BIM for FM. The FM personnel and management must acquire the skills needed to manage and regulate BIMs for FM. A comprehensive BIM for the FM specification must be produced to specify the information necessary to meet the needs of the corporate and FM functions as obtained for this specific necessity.

According to participants' responses, the survey findings showed how BIM might provide advantages to labor, productivity improvement, and accurate geometric information recordings. However, aside from the issues mentioned in the earlier literature in this case study, discussions with the real-estate developers and facility managers highlighted a new difficulty that is inherent in the significant lifetime disparities of BIM, FM, and building technologies. In this manner, FM organizations need to modify their business processes to be more flexible and more adaptable to diverse information and data standards during mid and long terms rather than dealing with only a specific technology.

The research findings add an input academics can make to developing FM BIM methodologies that comprehend and explain the customer's needs because this is critical to the success of BIM and FM. Researchers and practitioners use the highlighted difficulties and values to conduct studies identifying and addressing the ultimate success criteria for implementing FM BIM and ad hoc tactics to meet these factors.

The facility management industry takes a cautious approach to new technology, and its acceptability in the FM industry is limited until BIM has been proven to provide FM benefits. Furthermore, client demand for BIMs for Facility Management is minimal, exacerbated by a general lack of modeling and model usage coordination among project stakeholders. Finally, interoperability between BIM technologies and current FM systems, such as CAFM, remains a concern in the data and information transfer to the operation phase.

FM outdated systems are typically used for one or two decades in existing assets. Still, unless the transfer of BIM data to such mainframes aligns with or improves current operating modes and the value of BIM is revealed, facility managers are unwilling to prove the business models for using BIM. But even so, recommend that systems be integrated and display a BIM system attached to a traditional facilities management system.

Consequently, most contract forms still demand the delivery of paper papers comprising asset lists, product spec sheets, warranties, spare part entries, preventative maintenance plans, and other documentation. Unfortunately, this frequently results in inadequate and erroneous information that is difficult to acquire and use for enhancing FM efficiency. Thus, the value of BIM is in the FM application. Currently, most contracts demand the transfer of papers with equipment inventories, product documents, warranties, replacement component lists, preventative maintenance schedules, Etc. This information is vital to help the owner and facility managers' management of the installations and operations

As per the survey results, integrating IoT and BIM would improve productivity in speed, accomplishing service requests to access data, and pinpointing interventions.

In summary, procurement and legal and regulatory frameworks need to be investigated when it comes to FM enabled by BIM. Specific FM applications based on BIM include safety planning, inspection, and diagnostics, which should be researched further. Figure 43 depicts the BIM-enabled FM framework created by mapping the BIM implementation lifecycle research themes identified through article classification to the commonly cited and well-accepted technology diffusion theory. The research interest's distribution across research domains and sub-areas and research interests across time were

determined. The entire investigation uncovers the flaws in the knowledge corpus discussed in the context below.

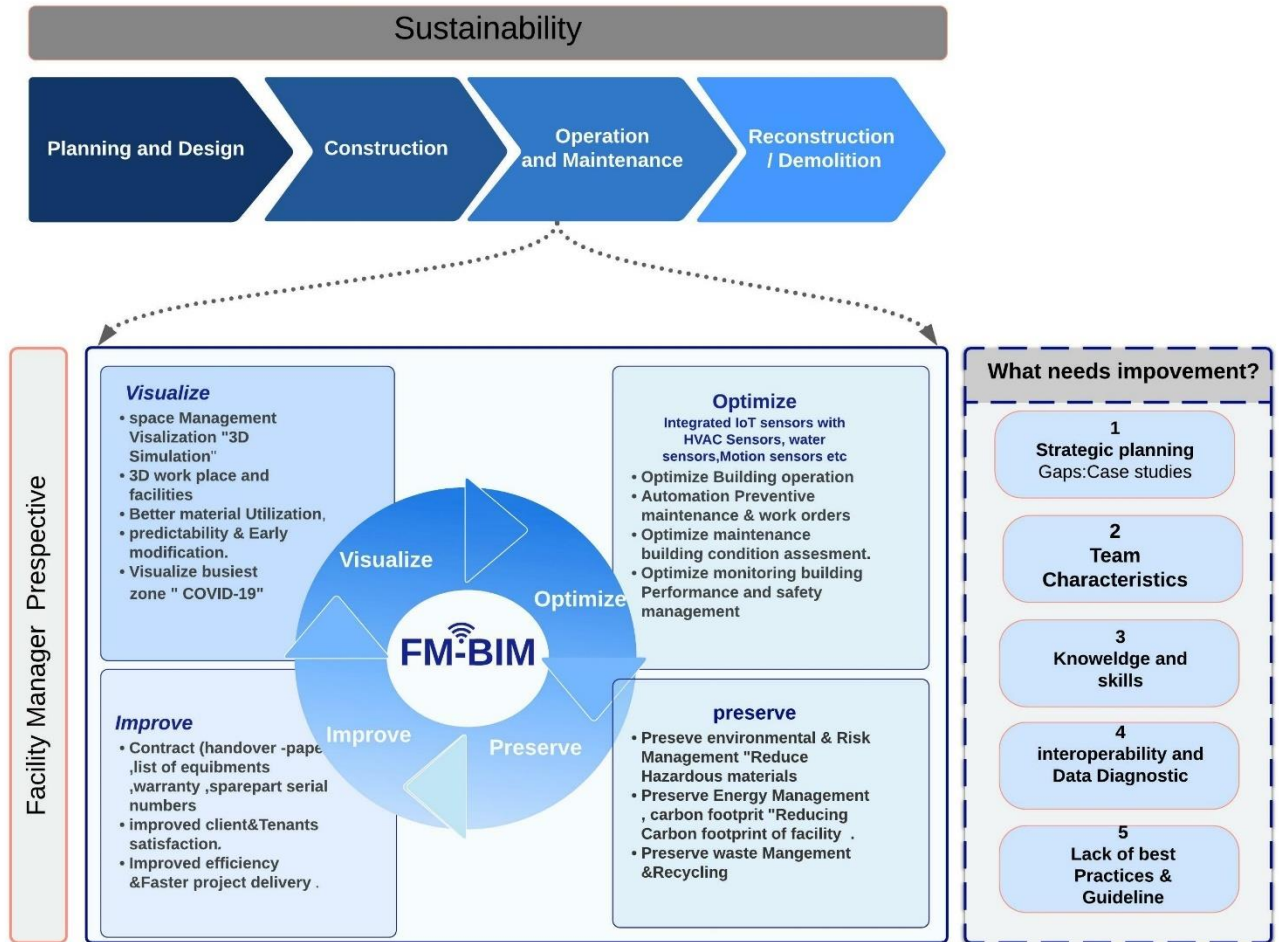


Figure 43: BIM-enabled FM Framework

The framework of the research focuses on how the BIM-IoT integration achieves sustainable FM. First, the planning stage deals with the relationship between the owners and designers and the contractors as the primary stakeholders. The owners' role is to communicate using model-aided design and approve and send comments and feedback to the designers to ensure that the design fits the owners' vision. After the input is altered, the designers finalize and complete the design using the initial models, feedback, the design drawing, construction drawing, and any documents needed. In this stage, BIM aids in any way possible to minimize the cost and time waste for an error-free flawless design. In this way, the contractors can apply the design efficiently.

The operation stage comes next with four FM-BIM goals: visualize, optimize, improve, preserve. In visualizing the FM, BIM provides access to visualize space management using 3D simulation and 3D workplace and facilities. In addition to providing better material utilization. Another advantage is the predictability and early modifications for any emergencies or malfunctions. In the current COVID-19 circumstances, BIM has been a critical solution for the visualization of the busiest COVID-19 zones. Next is optimizing operation integrated IoT sensors such as HVAC and water sensors. In this goal, the BIM-IoT integration targets the building operations, the automation preventive, maintenance condition assessment, and monitoring building performances. The third goal is improving the contract in terms of handover, document handling, inventories, warranties, spare parts, and serial numbers; basically, all the documents are needed. This goal aims for improved efficiency and faster project delivery. The final goal is to preserve the environment via lowering risk management. In this manner, the energy must be renewable with the most miniature carbon footprints and support waste management and recycling techniques and mechanisms.

According to the research findings, five significant challenges hinder any efficient, effective BIM-FM integration in the FM-first, the strategic planning, and the gaps in the case studies. Second, the team characteristics. Third, the knowledge needed for the efficient integration and the updated set of skills to achieve the best practice. Fourth, the interoperability and data diagnostic required for flawless implementation—finally, the lack of best practices and guidelines that provides a solid outline for future trials.

7.2 Conclusion

Today, various initiatives and events are aimed at improving society's understanding of environmental concerns and behavior. Nevertheless, sustainability and its application remain a challenge to several people, organizations, and event organizers. Therefore, the researcher opted to convey the subject of applied sustainability of facility management via an actual event to learn about sustainability, particularly about its obstacles and event planning potential. The primary goal of this thesis is to provide a plan framework to ensure the sustainable management of the facility.

The researcher's resources include observations, prior literature studies, and survey questions included in this master's thesis. Finally, in this final section of the dissertation, the conclusions from the framework are to aid and guide the researchers, owners, facility managers, real estate developers, and engineers to the benefit and gap by integrating facility management with BIM and IoT for the future reference.

BIM is the fantasy of improved quality and consistent data in the integration with facility management software systems. BIM provides the committee with more reliable data for effortlessly receipt, storage, combination with other information. BIM enables FMs to decide on the space, floor layout, hardware and maintenance of capital, energy utilization, and economic efficiency across the facility's whole life cycle. This is the comprehensive nature of the linked BIM and FM data; issues may be immediately recognized and forecasted performance leading to fewer faults in equipment and assets. In addition, maintenance engineers may view a 3D view of the property and its location together with all service records, specifications, and contract details before a maintenance visit, which reduces the number of trips and enhances reaction times. BIM saves time and money by reducing operating resources and time by ensuring that facility managers, specialists, administrators, and engineers work on a single programming file and update it in real-time. The master thesis research questions were answered in many different chapters, illustrated in previous case studies, and then collected from the detailed literature chapter. Furthermore, the researcher summarizes the responses in the conclusion section to resolve any discrepancies that may be addressed to the readers. The research offers a broader perspective in various phases of the best utilization for the BIM IoT integration.

Q1 What are the links between BIM and Facility Management in existing buildings? What are the links between FM and sustainable building operations?

There are different types of building uses (e.g., commercial, residential), in age (e.g., new, existing, heritage), and in ownership (e.g., private owner, governmental). Due to stakeholder requirements, supporting features involving design, building, maintenance, and deconstruction are required.

Part of the Facility Management organization's responsibility is for remodeling, renovating, or demolishing existing buildings

According to survey respondents, BIM is ideal for new, large, and more complicated buildings and is used in commercial, educational, hospitals, and various other building types.

According to the literature, these trends do not reflect the current use of BIM in existing buildings; while BIM methods are in place for new buildings, most existing buildings are not yet maintained, rehabilitated, or dismantled using BIM. The promising benefits of efficient resource management stimulate research to overcome building condition uncertainty and inadequate documentation typical in existing buildings.

BIM implementation in existing buildings is still limited due to high modeling and conversion effort. The challenges include updating and handling of information data in BIM and relations in existing building structures occurring in the past. In addition, it can be challenging to create geometric semantic BIM objects for existing buildings.

Due to a lack of data security and user confidence, BIM in facility management deployment in existing buildings would be hampered. However, because of the development in BIM implementation, there are numerous demanding future study prospects in this field in existing buildings.

There are relationships between facility management and sustainable building operation. Sustainable facilities management is a set of actions connected to facility investment, operation, and maintenance that promote facility sustainability within the decision maker's control. Making more sustainable decisions in this situation demands considering both the short- and long-term effects of viable options on facility stakeholders.

BIM enables FMs to make strategic choices on land usage, floor design, infrastructure and asset management, energy use, and cost efficiencies over the facility's entire lifecycle.

First and foremost, users' needs must be understood to support the organization's mission. The company's goals and mission include creating healthy buildings that encourage occupant safety, well-being, and more sustainable operations.

Q2 How can BIM frameworks be integrated and implemented to reduce operational GHG emissions through facility management?

GHG levels have continued to rise rapidly since the industrial revolution. Science, on the other hand, is attempting to cut GHG emissions thanks to technological advancements. BIM frameworks can be integrated and deployed in this way to reduce operational GHG emissions through FM.

Facility Management (FM) has a direct impact on building systems by determining maintenance and replacement actions. Building systems such as HVAC, lighting, water temperature, and building equipment all contribute to Operational Energy (OE), which significantly impacts carbon emission levels.

BIM frameworks can be integrated and deployed in this way to reduce operational GHG emissions through FM. Tyren building in Sweden is an excellent example of reducing and monitoring GHG emissions and how environmental issues affect the quality of life and, as a result, output.

The value of BIM-FM integration may be seen in implementing BIM models for more precise sensing and maintaining average or above-average levels of HVAC factors, temperature, and CO₂ levels.

By integrating BIM and IOT in Facility Management to make environmentally beneficial options, most carbon emissions impact may be controlled and reduced.

The ability to do more with less is one of the positive effects of IoT and analysis. Essentially, this implies that applied technology minimizes energy dependence, also decreases carbon emission.

On the other hand, the survey emphasizes the necessity of striking the appropriate balance to create a friendly working environment while reducing costs. An IoT and analytical device-enabled building, for example, avoid improper changes such as unauthorized access to the facilities management system or carbon emission reduction. As a result, IoT can be used effectively. Based on survey analysis, participants see the BIM capability to significantly compare different energy options to reduce environmental impacts and operational costs and maximize sustainability.

Q3 What are the future policies and procedures for FM development?

This research found that the legal and policy framework has received less attention than other aspects of FM BIM. Interoperability has been thoroughly researched in the technological field, but data-gathering systems, which are known to be challenging to install FM for older buildings, have not. There is also a low priority placed on advanced safety planning, inspection, and diagnosis. In addition, the BIM-enabled evaluation is an integral part of ongoing preventative maintenance.

A key area of problem is the lack of a legal and contractual foundation for adopting BIM broadly and BIM for FM specifically. For the foreseeable future, legal and liability requirements in the construction sector will necessitate that contracts between parties be presented in a facility textual and two-dimensional structured format. The first legal risk to consider is who owns the BIM data and how to safeguard it under copyright and other regulations. Licensing agreements are developing as a viable option in BIM policy, allowing restricted usage to another party while retaining copyright and absolute control. Unfortunately, this technique is constrained by issues with embedded data and model validation.

BIM can improve the contract in terms of handover, document handling, inventories, warranties, spare parts, and serial numbers; basically, all the documents needed

Despite the limited compatibility of BIM and Facility Management technologies, data analytics capabilities with the gathered data provide facilities managers and clients with insight into how people use this building, maximize sustainability, reduce operating costs, and generate the best user and consumer experience possible.

The framework has also been tweaked to match knowledge management theories due to the latest management technologies, such as a BIM model and Big Data databases.

Future technologies, like COVID-19 containment measures, may also be implemented. In addition, Automated procedures have the potential to increase sustainability in terms of reducing operation waste, conserving resources, improving safety in the workplace, and smart living.

Considering these developments, inquiring about the strengths of integrating the data found in BIM into the building management and maintenance stages is a must. Implementing BIM information models could contribute to a fundamental shift in the management of buildings and their facilities.

By integrating BIM and IoT, many benefits will be achieved and help facility managers, for instance, to sustain a client, all his expectations must be met. To do so, the facility manager must be able to respond to every service request promptly. IoT and analytics in facility management have the potential to provide the facility manager with real-time data. Thus, it allows the occupant to have a high-quality facility at a minimal cost rate.

A facility manager can find, supervise, and provide access to assets installed for an occupier using IoT-enabled devices and analytics. For example, a facility manager may use IoT and analytics to evaluate assets such as HVAC, escalators, ventilators, smoke detectors, Etc.

7.4 Research Gap and Recommendations

Despite the advantages and ease of access to BIM and IoT in FM, some challenges and complications impede the use of BIM and IoT in FM. The mainstream challenges are:

1. Gaps in strategic planning: Case studies: To avoid wasting time, effort, and money, it is critical to figure out what information works best with the organization's strategies. There is no case study with best practice and substantial evidence to prove the benefits of BIM for FM. The available case studies are unreliable and inaccurate in terms of possibilities and advantages and not difficulties.

There is a need for case studies and hard evidence to prove the benefit of BIM for FM and clarify practical challenges. It is essential that FM proactively defines the information requirements at the start point of the project life cycle, rather than waiting for the project closeout to collect information

2. **Team Characteristics:** Another problem is the facility management teams and facility owners' ability to manage information. Developing the auditing procedure's fundamental rules easier and building a technique for recognizing required information throughout the operation phase is critical.
3. **Knowledge and skills:** There is a lack of understanding of the prerequisites for BIM implementation in FM (e.g., what information is to be provided, when, and by whom), also the absence of a defined structure for roles, responsibilities, contracts, and liabilities. In addition, the shortage of BIM skills in the FM industry plus the industry's rigorous cultural approach to adopting new procedures, technology, and analytics allows you to accomplish more with less.
4. **Interoperability and Data Diagnostic:** Modeling requirements necessitate the use of strict BIM specifications. The interoperability and linguistic gap between BIM and FM technologies and the lifetime disparity, even though COBie was launched as the primary form of data interchange, managing data in the COBie format takes an excessively long period.
5. **Lack of best Practices & Guidelines:** BIM is not well understood by owners and facility managers. They are unsure how BIM can be applied in FM. the lack of methodologies that explain the actual benefits of BIM and IoT in FM is reflected by a limited demand for BIMs for FM by clients and operators.

According to the author, extensive training and seminars are required to educate the owner and operating team. Consequently, the importance of BIM-IoT integration is highlighted and proven its importance and efficiency. Thus, investing, enhancing, and boost the usage of BIM-IoT in facility management. Furthermore, to avoid unnecessary costs and increase sustainability throughout the facility's life cycle, it is advised that a facility Manager should be consulted and supported from the design and construction stages.

Energy consumption accounts for many O&M costs, which is higher than design and construction costs. The maximum budget from the total amount is consumed by excessive energy consumption in the building. Consequently, choosing low energy consumption systems for building facilities enables savings in building use. It is suggested that sensible selections select low-energy-use equipment and systems to save

operational costs during the planning and construction stage. As a result, the goal of the sustainable building process is met.

It's highly recommended that expanding in use of automation sensors special in HVAC systems which enhance building performance and helping for decreasing carbon emissions of the buildings

7.5 Future Research

Additional studies are needed to improve the integration of BIM and facilities improvement initiatives in line with the full use of BIM to boost manufacturing in the building sector. A lot of study needs to be done to investigate machine learning to make the raw data meaningful.

Future BIM-enabled FM models, such as automated surveillance and data analysis, are actively involved in decision-making, more interactive, and are connected to many systems. There is also no sufficient study of the effects of government policy or organization's policy on BIM-enabled FM; future research requires an impact analysis on this subject. The framework allows FM professionals to determine the stages of the FM life cycle and the gaps found for future research open routes.

In this manner, merging the Augmented Reality (AR) and Visual Reality (VR) with the BIM-IoT model will reach the best practice for the FM personnel to quickly and accurately fix emergencies. For instance, when fixing a ventilation malfunction in an airport, the technicians can easily access the quickest and shortest path. They have already been there virtually and already familiar with all the givens at the location.

Declaration of Authorship

I hereby declare that the attached master's thesis was completed independently and without the prohibited assistance of third parties and that no sources or assistance were used other than those listed. All passages whose content or wording originates from another publication have been marked as such. Neither this thesis nor any variant of it has previously been submitted to an examining authority or published.

Location, Date

Berlin, 30/7/2021

Signature of the student

Ahmed Aziz
30/7/2021

Appendix

Appendix A

The following survey is part of ongoing research by Metropolia University of Applied Sciences and HTW. We estimate that the survey will take less than 10 minutes to complete.

The survey has been compiled to capture insights into current mindsets and practices regarding the integration of BIM and IoT in Facility Management. The questions concern your approach to Facility Management and help direct future work towards realizing more sustainable Buildings.

The purpose of this research is to investigate and critically evaluate BIM as an FM tool, to augment and add value to building operation, maintenance, and decision-making



Developing a BIM based framework for Sustainable Facility Management

Thank you for participating in our survey. Your feedback is important.

The purpose of this research project is developing a BIM based framework for Sustainable Facility Management by integration BIM and IOT sensors . The forthcoming theoretical frame is viewed as a medium to aid facility managers and policymakers - and by implication incorporated in the decision-making process - in seeking and realizing greater FM flexibility, as to improve the ability of buildings to adjust for changing circumstances and technologies without excessive waste and conflict.

The present research defines facility management (FM) as "managing the building performance by integrating people, place, process, and technology to ensure the efficiency of the buildings environment." FM aims to provide the ultimate interaction and integration between human intellect and technological efficiency, as well as accuracy.

If you require more details, please do not hesitate to ask.

Researcher: Ahmed Aziz, Master's Student at Hochschule für Technik und Wirtschaft (HTW) Berlin.

ahmed.aziz@student.htw-berlin.de | www.htw-berlin.de

ahmed.aziz@metropolia.fi



Developing a BIM based framework for Sustainable Facility Management

consent

By choosing Yes at the end of this page, you are giving the creators of this survey consent to use your responses for academic purposes as highlighted in this page. If you require more details, please do not hesitate to ask.

Researcher: Ahmed Aziz, Master's Student at Hochschule für Technik und Wirtschaft (HTW) Berlin.

ahmed.aziz@student.htw-berlin.de | www.htw-berlin.de
ahmed.aziz@metropolia.fi

Project title:

Enhancing Facility Management by Integration Building Information Modelling (BIM) and Internet of things (IoT)

What will I be asked to do?

You will be asked to participate in the research, which involves responding to this digital survey questionnaire. The questionnaire's objective is to capture insights into current mindsets and methods regarding the integration of BIM and IoT in Facility Management. The nature of questions involves the various design approaches to Facility Management, as to direct future work towards realizing more sustainable buildings.

Please note that your participation is voluntary. You may withdraw from the study at any time, and you are free to decline to answer any question.

What type of personal information will be collected?

Should you agree to participate in the survey, you will be asked to provide the following information (all of which are optional):

- Years of experience in the Architectural, Engineering, and Construction (AEC) industry;
- The Highest academic degree related to the AEC industry.

What happens to the information I provide?

This is an anonymous survey and no personal information will be gathered. The collected data will be analyzed and will be solely used for the purpose of the research, submissions for academic and/or industry publications, and journal/conference publications.

1. The researchers will keep the collected data for a minimum of 5 years after successful defense of the Master thesis in a cloud-based storage service (cryptographed and password-protected). Only the research team will have the means to access the data. The research team has no plans to use the data for future research purposes.

You are free to decline to answer any question. If you choose to withdraw at any time, all your previous answers will be deleted and will not be used in the study. In a digital survey, participants can withdraw from the survey at any point (with their responses not recorded) as long as they choose to press the "Exit" instead of "Submit." However, if the "Submit" button is pressed, the responses are added to the aggregate results and cannot be withdrawn as there is no way to identify who entered the responses.

By choosing the YES option at the bottom of this page, you are indicating that:

1.You understand to your satisfaction all the information provided regarding your participation in this research project;

2.You agree to participate in this survey.

Thank you very much for the time and expertise you will contribute to my dissertation research.

Have you read and understood the text on this page and give consent for the answers you provide on this survey to be used for the study described above?  

Yes

No



Developing a BIM based framework for Sustainable Facility Management



Participant Profile

* 2. Please indicate your years of experience in the Architecture, Engineering and Construction Industry (AEC)



- 1-3 years
- 3-5 years
- 6-10 years
- Over 10 years

* 3. Please indicate your professional background within the firm you are affiliated with:



- Architecture
- Contractor
- Real Estate Developer
- Facility Manager
- Construction Management / Engineering
- Software
- Other (please specify)

* 4. Please indicate the scale of your firm  



- <100
- 100-500
- 500-1000
- >1000

* 5. How often do you plan early to account for operational facility management on a project basis?  



- Every project
- Few projects
- All projects
- Never
- I am not sure

6. What categories best describe the buildings/facilities you managed (select all that apply)  



- Residential
- Commercial
- Offices
- Educational
- Industrial
- Infrastructure
- Other (please specify)

7. Please indicate the primary geographical location of projects you (and your firm) design/manage (select all that apply)  

- Africa
- Asia
- North America
- India
- Europe
- Other (please specify)

8. What activities do you use your facility management software for? (select all that apply)  



- Asset Management
- Contract Management
- Disaster Management
- Energy Management
- Environmental Management
- Fleet Management
- Move Management
- Preventative Maintenance
- Room Scheduling
- Security
- Space Management
- Other (please specify)

9. Do you use any of the following software to support facility management? (select all that apply)  

- BIM software (e.g., Revit, ArchiCAD, Solibri, Tekla)
- CAD software (e.g., AutoCAD)
- Computer-aided facility management (CAFM) software
- Computer Integrated Facility Management (CIFM) software
- Computerized Maintenance Management System (CMMS) software
- Integrated Workplace Management System (IWMS) software
- None of the above
- Other (please specify)



Developing a BIM based framework for Sustainable Facility Management

Benefits and Challenges

10. In your perspective, what are the limitations (if any) of standard facility management?  


	Very insignificant	Neutral	Significant	Very significant
Inadequate data transference and exchange	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Lack of 3D visualization	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Lack of location based/ geographic functionality	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Poor data accessibility	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Poor data interoperability	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Other (please specify)


11. From your perspective, what benefits can be achieved from the integration of facility management with BIM and IoT sensors?  

	Very insignificant	Neutral	Significant	Very significant
Cost Reduction	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Customer Satisfaction	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Decision Making	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Efficiency	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Strategic Management	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>



Other (please specify)

12. What do you consider the uses of BIM to be for facility management?  



	Very insignificant	Neutral	Significant	Very significant
3D Visualization	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Asset Management	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Database and data management	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Maintenance	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Space management	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Sustainability and energy management	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Other (please specify)	<input type="text"/>			

13. What do you perceive as barriers regarding the adoption of BIM and IOT for FM?  

	Very insignificant	Neutral	Significant	Very significant
BIM & IOT tools are not designed to support facility management	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Cost/ Budget	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Lack of BIM & IOT knowledge amongst building owners and operators	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Other (please specify)	<input type="text"/>			

14. Which of the following are issues that your organization is facing in trying to understand or implement BIM and IOT in your work place?  

- Basic knowledge of BIM and its usefulness to your organization
- Management Commitment
- Training and Support
- Financial Issues
- BIM Contracts
- BIM Guidelines and Specifications
- IT Security Issues
- Hardware & Software Costs
- Other (please specify)

15. Do you currently use any smart devices (e.g., RFID tag, access card, etc.) to operate your building?  


- Yes
- No

16. What has been/do you expect to be the biggest benefit of installing smart technologies in your building?  

- Creating a more comfortable environment for staff and/or customers
- Reducing cost of changing occupancy and configuration (churn)
- Helping staff do their jobs more efficiently
- Improving security
- Cutting energy usage/costs
- Other (please specify)

Developing a BIM based framework for Sustainable Facility Management



Added Value

17. From your professional experience in the AEC industry, rate the top five (5) items that are the cause of work (maintenance) orders:  0

- Lighting issues
- Moves / Adds / Changes
- Furniture and Equipment repair
- Emergencies (pipe burst, short circuit, etc.)
- Power quality and reliability
- Indoor Air Quality (IAQ)
- Heavy floor loading
- Weather impacts
- Other (please specify)

18. Do you currently use BIM & IOT sensors for tracking data?  0

- Currently do not use.
- Currently use.
- Plan to use.
- Think it is a good idea to pursue further
- Other (please specify)

19. Do you agree or disagree with the following statements?  

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
BIM&IOT use in facilities management should be considered the future of effectively managed facilities	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
BIM will improve productivity of facilities management processes	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Costs associated with implementation of BIM (e.g., hardware, software and staff training) outweighs the financial gains of BIM&IOT Sensors for FM	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
The use of BIM& IOT in Facilities Management will enable Facility Managers to effectively manage and optimize maintenance services	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Appendix B

The target population was recruited through online open-source professional and academic networks, i.e., LinkedIn, Academia, and Research Gate. Individuals were invited to participate in an online survey of issues concerning “facility management, flexibility, and integrated facility management.” An invitation or post was circulated via direct contact, e.g., LinkedIn or Academia messages, or posting on relevant LinkedIn groups with at least 1000 members to approach an active and up-to-date audience

The link of Survey: <https://www.surveymonkey.com/r/MV6CQ27>

NO.	Group Name	Number of members	Link
1	International Facility Management Association	76.9 K	International Facility Management Association
2	Integrated Facility Management	40.6 K	Integrated Facility Management
3	Reached Integrated Facility Management	38.4 K	Reached International Facility Management Association
4	Property and Facility Management Innovators (PFMI)	16.9 K	Property and Facility Management Innovators (PFMI)
5	MM - Maintenance and Facility Management	13.5 K	MM - Maintenance and Facility Management
6	Critical Facility Management	11.9 K	Critical Facility Management
7	Global Real Estate & Facility Management - FORUM	11.5 K	Global Real Estate & Facility Management - FORUM
8	Facility Management Strategic Sourcing	7.4 K	Facility Management Strategic Sourcing

9	FMA Australia - Facility Management Association of Australia	7.2 K	FMA Australia - Facility Management Association of Australia
10	Facility Management by Arya Group	6.1K	Facility Management by Arya Group
11	Facility Management & Support Services	5.9 K	Facility Management & Support Services
12	ABRAFAC - Associação Brasileira de Facility Management, Property e Workplace	5.8 K	ABRAFAC - Associação Brasileira de Facility Management, Property e Workplace
13	Facto.nl - voor professional facility management	4.7 K	Facto.nl - voor professioneel facility management
14	Sustainable Facility Management	4.4 K	Sustainable Facility Management
15	Construction, Facility Management & Security Leaders' Challenges & Solutions	4.2 K	Construction, Facility Management & Security Leaders' Challenges & Solutions
16	Facility Management Professionals Group	3.9 K	Facility Management Professionals Group
17	Hospitality Facility Management	2.8 K	Hospitality Facility Management
18	Dutch Facility Management Professionals	2.8 K	Dutch Facility Management Professionals
19	Corporate real estate Administration & Facility Management Gp.	1.8 K	Corporate real estate Administration & Facility Management Gp.
20	FME (Facility Management en España)	1.5 K	FME (Facility Management en España)

21	EFMC - European Facility Management Conference	1.1 K	EFMC - European Facility Management Conference
22	Integrated Facility Management Europe	1 K	Integrated Facility Management Europe

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