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Faculty of Business Economics

Master of Management

Master's thesis

Fostering AI Application/Integration in Facility Management from a Quadruple Helix Perspective

DI HUONG GIANG DOAN
Lin Yang

Thesis presented in fulfillment of the requirements for the degree of Master of Management, specialization Strategy and Innovation Management

SUPERVISOR :

Prof. dr. Jean-Pierre SEGERS

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YANG LIN & DOAN DI HUONG GIANG

Executive Summary

1. Research Purpose

Facilities management (FM) plays a vital role in improving the quality of life of people and the productivity of businesses.

With the rapid development of artificial intelligence (AI), the convenience and experience it brings have begun to show in all aspects of people's lives. Every industry sees AI as the future and is spending a lot of money to develop AI-powered tools. FM needs to keep pace with The Times and integrate AI to improve its services to meet customers' higher expectations and achieve sustainable growth.

This study aims to explore the ecosystem of the FM industry from the perspective of the quadruple helix model. The aim is to understand the status quo and make recommendations on how to strengthen the links between the four segments - government, industry, academia, and society - to promote AI application and integration.

2. Research Methodology

This study used a qualitative research approach, utilizing semi-structured interviews to collect primary data. The questions were divided into many clusters to support answering three research questions. The answers were then coded for data analysis. There were seven respondents who joined the interview, and they have different levels of expertise and positions in the FM industry. This methodology allows us to gain practical insights and recommendations from different perspectives. Six out of seven interviews lasted 60 to 65 minutes, one interview lasted 45 minutes. All the interviews were carried out online through online platforms such as Zoom and Google Meet due to the geographical distance of respondents who live in different cities and countries.

3. Findings

After conducting interviews with respondents, many findings were highlighted and discussed. Clearly, AI integration is an inevitable evolution in FM, following the global trend in technology development. Despite being considered a laggard in technology innovation compared to other industries, FM is moving towards AI integration due to the many benefits it can provide. These benefits include reducing costs and improving operation efficiency, enhancing occupant experience, contributing to sustainability by saving energy, reducing emissions, and decarbonization.

There are 4 major advantages that can be considered as key drivers for FM to integrate AI. Firstly, there is a large amount of underutilized data from buildings, which is an important source to feed AI-powered technology. AI can leverage this available data to optimize efficiency. Secondly, there are many technology companies that FM can collaborate with to help them integrate AI, given that FM companies are quite slow at innovation. Thirdly, major international FM companies are investing heavily in new technologies like AI, which lead the innovation trends in this industry. Lastly, the interconnected nature of FM with various organizational departments is an important facilitator for

the implementation of AI as it can allow FM to learn good practices from other more developed industries like banking.

Besides many drivers, FM also faces many challenges when adopting AI. Our finding highlighted six significant barriers. The legacy technology, which is a disparate and outdated system, lacks a unified Building Management System (BMS). Besides that, a lack of awareness and understanding of AI and its capabilities, along with daily routines generated by long-history corporations and an aging workforce led to the reluctance to change, hindering AI adoption. FM companies also face conflicting benefits, which is known as the "Split Incentives" phenomenon, between reducing operating costs for clients and maintaining their own revenue. Furthermore, AI implementation requires a shift in change management and staff model to ensure that all the stakeholders are ready to adapt to new technologies. Data management and data privacy, such as GDPR regulations, are highlighted as critical concerns. Lastly, the skills gap, created by the shortage of digital knowledge, high turnover rate, insufficient skills, and resource constraints, hinders both startups and established FM companies from fully embracing AI.

The FM ecosystem is still in the early stages when it comes to collaboration to foster AI integration among four components of the Quadruple Helix model - government, industry, academia, and society. We discovered a lack of a clear, unified shared vision among the four stakeholders in the FM ecosystem. The cooperation and communication in the ecosystem are still weak. In addition, the current financial framework is insufficient to adequately support the development of social participation within the FM ecosystem. Actively encouraging and motivating social participation as an important element in the ecosystem is the driving force for the application and implementation of AI in FM. This study highlights the lack of clear guidelines within the existing FM field that contribute to enhanced cooperation among the four pillars. Guidelines may contain standardized processes for collaborative project development and the establishment of platforms that facilitate cross-domain dialogue.

Our findings highlighted the important role of IFMA as an anchor in the FM ecosystem. IFMA is dedicated to educating the public about the importance of FM and AI's transformative role. In addition, it actively bridges the gap between academia and industry. Moreover, IFMA used its influence to lobby and advocate for regulation and guidelines with the government to shape the future trajectories of the FM industry. IFMA's multifaceted approach emphasized its vital role in leading the FM industry to move forward.

There are five key solutions suggested by our correspondent to strengthen linkages between four stakeholders within the Quadruple Helix Model to enhance AI integration in FM. Skill development is the most prioritized approach, making sure FM professionals are equipped with sufficient AI skills and competencies to close the knowledge gap in the workforce. Furthermore, fostering information sharing between the four components of the Quadruple Helix model (government, industry, academia, and society) is crucial for fostering AI use and innovation. In addition, a clear regulatory framework and support from the government are important to initiate and accelerate AI

advancements. Lastly, user friendly and engaging AI applications are believed to address digital skill barriers, facilitating AI adoption in FM.

4. Critical Considerations and Recommendations

Life-long learning and FM training

For current or potential FM employees, it is crucial to continuously learn new skills (especially AI tech) to keep pace with the times for the development of the whole industry.

Abundant interactions between academia and the FM industry

Academia should work more closely with industry to provide new technologies and bridge the gap between theory and practice. On the other hand, the industry should actively strengthen its ties with academia, providing resources, mentorship programs, and internship opportunities, which will attract more research related to AI application and integration in FM.

Creating collaborative innovation strategies to engage FM users

The collective innovative power of society has not been exploited in the FM industry. From the experience of other fields, the driving force of society may bring unlimited possibilities for AI integration in FM.

Adapting regulations for AI advancement and FM industry standards

Revise regulations to adapt to the progress of AI, giving full consideration to user interests and privacy. And comply with evolving industry standards in the field of facility management.

Continue to expand and deepen the anchor role of IFMA in the worldwide

Through research, we found that IFMA closely linked the FM industry and the other three pillars through various interactions in the FM ecosystem, thus promoting the development of the industry. The role of IFMA must continue to flourish.

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1. Problem Statement

In our dynamically evolving contemporary landscape, artificial intelligence (AI) is reshaping every aspect of people's lives, including facility management. The integration of AI into facility management marks the beginning of a new era characterised by improved efficiency, sustainability, and innovation (Pan et al., 2021). According to the latest market research report by Fortune Business Insights (2023), "The global facility Management market size will reach a valuation of US $1.26 billion in 2022. The forecast shows a growth trajectory from $1,291.6 billion in 2023 to $2,031.4 billion in 2030, reflecting a compound annual growth rate (CAGR) of 6.7% during the forecast period." There is no doubt that AI is a key force in this critical field. It has fully demonstrated its ability to predict maintenance requirements, optimize energy consumption, enhance security measures, and streamline operational processes (Bechina et al., 2022). We are at a critical stage in the transformation of facility management. Currently, building information modeling (BIM), modern construction methods (MMC), and rapidly evolving technologies and digital methods such as virtual reality (VR), augmented reality (AR), artificial intelligence, 3D, and Internet of Things (IoT) take center stage in FM innovation, and developed on the back of indispensable data that provided critical information. These technologies are accelerating the design, delivery, operation, and maintenance of the built environment in unprecedented ways.

The International Facilities Management Association (IFMA) defines facilities management as "an organisational function that integrates people, places, and processes in the built environment with the aim of improving the quality of people's lives and the productivity of core operations". The basic principle of "people, processes and places" has been adopted since 1982. It may seem simple, but it contains 11 core competencies (IFMA, 2020). The facility management function is similar to that of a supplier, which meets the needs of its customers by providing professional management services for facilities (Atkin & Brook, 2021). In short, facility managers are responsible for handling the operational side of the business and ensuring that customers can focus on their core interests (At-It, 2023).

The self-owned complexity of facility management, combined with the mediating role between facility managers and demand organisations, often leads to a gap between actual and expected innovation rates. The current academic research focus is mainly on the technical aspect and often ignores the behavioural outcomes of the end users. Practitioners said that despite increased awareness about technology, there are still flaws in the solutions that engage end users to optimise facilities. In addition, not all FM companies have sufficient capacity to deal with the challenges posed by sustainability; It is worth noting that SMEs encounter many difficulties in implementing various sustainable developments (Sawhney et al., 2020).

Figure 1: How facility management aligns with the demand organisation's strategy (ISO 41001, 2018)

The potential application of the quadruple helix perspective has brought great hope to the field of architecture and built environment management, but its utilization is still limited (Pulkka et al., 2016). The facility management (FM) industry often has different actors taking on different tasks to achieve their common goals by collaborating across projects. From this point of view, it is surprising that the implementation of the quadruple helix model is not fully utilized. There is a considerable degree of interdependence between these cooperative actors, both within individual projects and at the system level, where actors rely on their reliable collaborators to guarantee the achievement of project objectives. Given the uniqueness of the FM industry, we believe that the quadruple helix model is an appropriate model for the innovation period. The quadruple helix model builds on and extends the triple Helix paradigm by extending participants to the range of their social contexts. The triple helix shows the importance of the knowledge economy, while the quadruple helix emphasizes the wider knowledge society and knowledge democracy. It further explains the initiative of civil society, democracy, and its social and environmental background in the knowledge production system (Carayannis et al., 2012). This extended framework provides a comprehensive perspective on the intricate interactions between academia, industry, government, and society that drives technological innovation in the field of facility management. At the same time, the organizational framework for designing innovation needs to be consistent with the company's business model (BM) to create the best environment for innovation to flourish (Carayannis & Provance, 2008).

We use a quadruple helix perspective to delve into the integration of AI in facility management. This study carefully examines the interrelated relationships and respective roles of academia, industry, government, and society in practice. It aims to gain insight into how these four pillars work together to shape a good ecosystem, which in turn promotes the effective integration of AI in facility management practices. By examining the multifaceted dynamics among these stakeholders, this

study aims to provide practical implications for the real world through an analysis of the complexity of the ecosystem of facility management and AI integration in a theoretical framework.

2. Literature Review

Facilities management (FM) is an integrated, multifaceted discipline that intertwines people, places, and processes in the built environment from different dimensions. This literature review initially describes the scope and evolution of the discipline and explores the dynamic landscape of facility management. From the emergence of technology integration and data-driven approaches that are revolutionising FM practices, to a comprehensive exploration of the capabilities that artificial intelligence (AI) can achieve in FM, this review examines the transformative potential of enhanced AI application and integration within the thought spiral model to reshape the FM landscape. Emerging trends and technologies in FM are a focus, and the present paper pays particular attention to the emerging field of artificial intelligence. This section takes a closer look at the application and integration of AI in facility management, shedding light on the opportunities and challenges inherent in this rapidly evolving technology field. Furthermore, the complex ecosystem of facility management, including its core actors and the quadruple helix model, is studied in depth to gain a comprehensive understanding of the collaborative dynamics within the field.

2.1 The On-going Evolution of Facility Management

2.1.1 Facility Management as a Discipline and its Scope

The concept of facility management (FM) originated in the 1970s. The Herman Miller Corporation conference on "the Impact of Facilities on Productivity" marked the emergence of FM on the historical stage as a separate field of research and practice. Since the late 1980s, FM has gained more and more recognition and attention in the real estate and construction industries and has gradually developed into a mature discipline and profession (Nor & Azman, 2014). In 1980, the International Facilities Management Association (IFMA) was established, which is the world's most important professional association for FM. The number of its members continues to increase significantly every year, which also proves the rapid development of the industry (Linda et al., 2001).

Over the past three decades, FM has undergone continuous transformation. It is no longer limited to managing tangible assets such as buildings, furniture, and equipment. It has been enriched to intangible elements, often referred to as "software": including people management, process, environment and user health and safety measures (Becker, 1990; Alexander, 1999).

The Technical Committee ISO/TC 267 Facility Management was established in 2012 and developed the initial standard ISO41011 in April 2017. The standard defines facility management as "an organizational function integrating people, place, and process within the built environment with the purpose of improving the quality of life of people and the productivity of the core business" (ISO, 2022a). Facilities management covers a wide range of services, including real estate management, contract management, change management, human resources management, financial management, and health and safety management (Kamaruzzaman & Zawawi, 2010). Sophisticated facility management ensures user satisfaction and optimal value delivery in a risk-filled environment, balancing the numerous interconnected factors that affect the well-being of people and organizations within a building (Aktin & Brooks, 2021).

In the 21st century, FM has evolved further, placing greater emphasis on sustainable practices. Sustainability within FM integrates environmental responsibility with operational efficiency in the built environment. This strategic pursuit involves eco-friendly practices, resource optimization, and the adoption of green technologies aimed at reducing the ecological footprint associated with facilities. Sustainable initiatives offer tangible benefits such as reduced energy consumption and increased productivity. Evaluating long-term viability and considering green alternatives through life cycle costs (LCC) and total cost of ownership (TCO) analyses provide comprehensive perspectives. Facility managers, positioned to oversee this process, often champion sustainable initiatives, delivering lasting value through strategic planning and implementation (Hodges, 2005).

Figure 2: 11 Core Competencies of Facility Management (IFMA Knowledge Library, 2023)

The COVID-19 pandemic has placed new demands on the relationship in which individuals interact with public facilities. This has led to the further consolidation and strengthening of the people-oriented approach in facility management (Park et al., 2022). At the same time, the shift has triggered more companies to pay attention to the competitive landscape of employee experience and talent recruitment. Enterprise users are increasingly recognizing the need to design workspaces beyond the basic requirements of employees, so they are actively investing in a richer employee experience. The human-centered evolution of facility management reflects broad societal trends to prioritize well-being and user experience in various domains, especially in the built environment (Van der Voordt, 2022).

2.1.2 Technological Integration and Data-Driven in Facility Management (without AI)

Emergence of Computer-Aided Facility Management (CAFM)

Over the past few decades, technology and data-driven approaches have been increasingly integrated with facility management practices. It is important to note that facility management practices always keep pace with advances in information technology. The recession of the late 1980s and early 1990s forced companies to delay their maintenance programs, resulting in a large backlog of projects. This is where innovative software comes in. It combines building defect data from physical audits with financial models and computer-aided facilities management (CAFM) software. This software with multimedia capabilities proved very useful in forecasting and strategic planning, highlighting the role of technology in evaluating real estate and facilities (Teicholz, 1995).

Advent of Building Information Modelling (BIM)

In the early 2000s, building information modeling (BIM) received a lot of attention as a collaborative method that includes both architectural design and construction. It is a novel integration of tools from design, architecture, and engineering disciplines including energy and structural analysis, scheduling, progress tracking, and site safety (Becerik-Gerber, 2012). BIM shows great advantages in collaborative management of the building life cycle. However, because it integrates almost comprehensive construction operations, it has high technical requirements for implementation. This limits the promotion of BIM and thus affects its potential.

Rise of the Internet of Things (IoT)

In the 2010s, the adoption of IoT devices and sensors has become widespread, and real-time data from different building systems can be collected. The combination of IoT and technological advances creates an integrated ecosystem conducive to monitoring and managing facilities. Subsequently, this ecosystem extends to the financial operations, administrative paperwork, and customer service encompassed by FM. Through the deployment of interconnected devices and sensors, IoT accelerates the timeliness of data collection, thus forming an effective method for FM to supervise the operation of facilities. This integration enhances operational visibility and helps generate informed decisions, largely optimizing facility management processes (Sarkar, 2021).

Smart Building Technologies

The concept of smart buildings also emerged in the 2010s. Its emergence marked a "paradigm shift" in facility management. Smart building technologies integrate system interconnection between lighting, HVAC, security, and other building functions. These technologies use advanced sensors and communication networks to realize real-time monitoring and control of the building environment, and then automatically respond to emergencies and timely user needs. Smart buildings simultaneously address the needs of sustainability, energy efficiency, and residential comfort, marking a major evolution in facility management (Aliero and others, 2022; King & Perry, 2017).

2.2 Artificial Intelligence Overview

Artificial intelligence (AI) is a subset of computer science. It aims to give computers the ability to mimic human perception and learning. These abilities include perception, knowledge expression, reasoning, problem solving and planning (Pan & Zhang, 2021). Ultimately, computers can take the

place of humans in dealing with complex, ill-defined problems in a conscious, adaptive, and intelligent way.

DARPA's John Launchbury (2017) divides the evolution of AI into three important phases (waves): Hand-crafted knowledge (wave 1): In this initial phase, AI systems are designed to deal with reasoning on narrow problems. AI at this stage lacks learning ability and is limited in dealing with uncertainty. Statistical learning (second wave): This phase is dominated by data-driven methods. The advent of machine learning (ML) enables systems to learn from experience, build models and make predictions without having to be explicitly programmed. However, ML has limitations in context understanding and reasoning ability, especially when training data is biased. Contextual adaptation (Wave 3): AI evolves to the current stage, which emphasizes the regeneration of knowledge in the system and aims to achieve decision-making capabilities that mimic humans. The third phase of AI evolution seeks to create intelligent systems that can adapt to context. Only in this way can AI become a trusted partner of humans.

The emergence of AI marks a revolution in technological progress. It provides humans with unprecedented problem-solving and automation capabilities. The real contribution of AI technology lies in its actual deployment in existing systems and seamless integration with existing technologies. Integrating AI into workflows is actually strategically integrating AI capabilities into workflows. This can be done through custom applications or systems integrating AI models and algorithms. This integration enables businesses to improve their workflow; Make data-based decisions. Realizing the full potential of AI technology can also help companies explore greater work efficiency and profit growth. (Fuller et al., 2022).

The following figure summarizes the main members of the AI family. Among them, various technologies, such as machine learning (ML), natural language processing (NLP), natural language understanding (NLU), optical character recognition (OCR) and chatbots, are key tools for implementing and deploying AI systems. Of these, ChatGPT was released in late 2022. ChatGPT's ongoing upgrades mark a crowning achievement in generative artificial intelligence in the field of complex natural language processing (NLP). It has brought immeasurable opportunities to various industries in just one year.

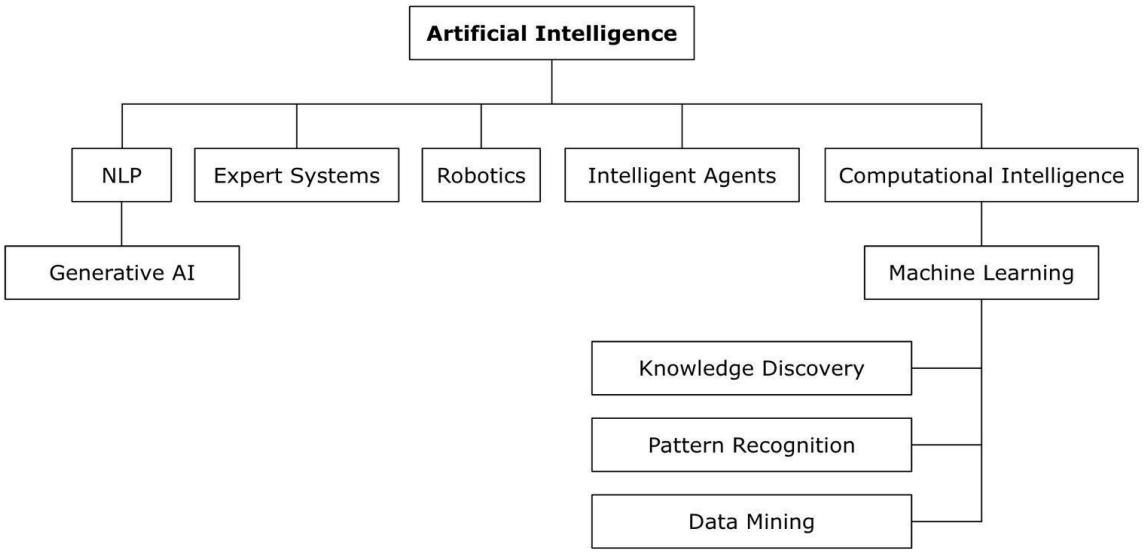

Figure 3: Key elements of the AI family tree (Anifowose, 2021b)

2.3 Ecosystem of Facility Management

2.3.1 Quadruple Helix Model

Innovation studies are replete with innovative theories that try to tap into the emergence of modern civilization. The Triple Helix and Quadruple Helix models have become two of the most frequently applied conceptual frameworks in innovation research (Cai et al., 2022). Originally proposed by Etzkowitz and Ledesdorf in 1995, the Triple Helix Model aims to describe the dynamic relationship that exists among four stakeholders (government, academia, industry) to foster "entrepreneurship, innovation, and economic growth in a knowledge-based economy" (Etzkowitz and Leydesdorff, 1995; Leydesdorff, 2010). Despite the Triple Helix Model's rapid growth in popularity in innovation research, several critics have questioned how well it explains certain phenomena (Cai et al., 2020), especially after the Quadruple Helix model was introduced by Carayannis and Campbell (2009), which included public or civil society as the fourth helix. According to Campbell (2011), the Quadruple Helix characterizes the "knowledge society" and "knowledge democracy," while the Triple Helix serves as a fundamental core framework of innovation for the "knowledge economy".

Quadruple Helix Innovation System Framework offered a more comprehensive view of knowledge creation as well as innovation application by integrating the "public" into modern innovation systems (Carayannis and Campbell, 2011). It prioritizes innovative users and promotes the creation of inventions that are useful to users - civil society (Carayannis et al., 2018). Users or citizens are the primary drivers of innovation processes. Arnkil et al. (2010) suggest that the level of user engagement may be described by the term "design by users,". In accordance with this point of view, users engage in their roles as lead users, co-developers, and co-creators to build new and creative products, services, and solutions (Carayannis et al., 2018).

It is suggested that the Triple Helix Model, which emphasizes top-down institutional policies and governments, be applied more frequently in Western nations (Leydesdorff and Meyer, 2007). By further introducing the role of civil society, the Quadruple Helix Model integrates top-down policies and bottom-up grassroots efforts to co-create knowledge and value, which can be used in both developed and developing countries (Park et al., 2014).

2.3.2 Ecosystem Definition and Stakeholders

2.3.2.1 Ecosystem Definition

The literature on ecosystems emphasizes that ecosystems are a means of conceptualizing business logic based on shared goals, activities, or other interdependencies among actors, instead of their existing network roles or industry boundaries. Moore (1993) proposes that ecosystems are a way of organizing business activities around a common set of goals, rather than around individual firms or industries. Similarly, Adner (2017) suggests that ecosystems are a means of coordinating the activities of multiple firms to create value for customers. According to Jacobides et al. (2018), ecosystems can be used to conceptualize business models that rely on interdependent relationships among actors, rather than on traditional industry boundaries. This perspective is particularly relevant in the context of the digital economy, where companies increasingly rely on complex networks of partners and collaborators to generate value.

The ecosystems framework is a compelling concept in the construction and FM sectors, but surprisingly underutilised (Pulkka et al. 2016). This is surprising as the construction sector and Facility Management are usually characterized as having a wide range of players who carry out diverse task duties but collaborate to accomplish shared goals in a variety of building projects (Kytömäki, 2020). In addition, the construction industry has traditionally been described as poorly innovative, primarily due to the emphasis placed on project performance, which over time impedes learning and innovation (Dubois and Gadde 2002). In addition, adopting and maintaining innovations is made more challenging by sector-specific institutional logic and firm- or project-level processes (Winch 1998).

2.3.2.2 Four Pillars and IFMA in the Facility Management Ecosystem

2.3.2.2.1 Industry

It is suggested that innovations in FM companies are frequently one-time commitments, and maintaining innovations has been shown to be difficult (Goyal and Pitt, 2007). According to Eley (2001), FM companies typically have difficulty reacting to recommendations that call for adjustments to their regular operating procedures. Pitt and Tucker (2008) suggest that the FM innovation process should be guided by appropriate performance monitoring and benchmarking, while Goyal and Pitt (2007) suggest that innovation management principles should be a part of everyday work for staff at all levels in the FM companies. In addition, Leiringer and Cardellino (2008) state that a large portion of academic studies that rely on narratives from influential figures may be pro-innovation

biased. However, the FM sector is still widely perceived as having a poor level of innovation today (Kytömäki, 2020).

However, due to the rise in urbanization and industrialization, FM has grown significantly during the past twenty years. The global facility management market is expected to grow at a compound annual growth rate (CAGR) of 6.7% from $1,291.6 billion in 2023 to $2,031.4 billion by 2030 (Fortune Business Insights, 2023). Growing real estate investment has accelerated the development of smart buildings. Due to the growth of these smart buildings, a network connecting lighting, sensors, windows, doors, HVAC systems, and CCTV cameras in this business has become a crucial preventative maintenance task, which leads to the demand for facility management. When it comes to incorporating technological developments, service providers in developed and developing economies - like the United States, the United Kingdom, Germany, and China - face three main challenges. The three main challenges are inadequate understanding of how to apply technology in their work; lacking guidance about data delivery and requirements; and interoperability (technical issues) (Fortune Business Insights, 2023).

2.3.2.2.2 Government

AI regulations

There is currently no set of rules or guidelines for governing the use of AI in the FM industry. However, AI regulation has become a key area of policy concern all over the world in recent years due to its fast development. According to Fazlioglu (2023), different nations have approached AI in different ways, as each reflects its own legal framework, customs, and culture.

In the US, the government has taken a variety of steps to control the application of AI in the country. In October 2023, President Biden signed an executive order to make sure that the United States takes the lead in embracing the potential of AI and mitigating its risks. Besides protecting Americans' privacy and advancing equity and civil rights, the order also creates new guidelines for AI safety and security, protects workers' and consumers' rights, encourages innovation and competition, and supports American leadership globally. The order demands that developers of the most powerful AI systems grant the US government access to their safety test results and other important information. To guarantee the safety, security and reliability of AI systems, it also creates standards, tools and tests. The National Institute of Standards and Technology will set up strict guidelines for intensive red-team testing to ensure safety before release to the public. The Department of Homeland Security will set up the AI Safety and Security Board and apply similar standards to vital infrastructure industries. Cybersecurity, chemical, biological, radiological, and nuclear hazards, as well as the risks posed by AI systems to critical infrastructure, will all be under the oversight of the Departments of Energy and Homeland Security (The United States Government, 2023).

In China, the Cyberspace Administration of China (CAC) introduced the "Interim Measures for the Management of Generative Artificial Intelligence Services" on July 13, 2023. This set of regulations outlines the Chinese government's approach to overseeing providers of generative AI services to the public in China. The regulations cover various aspects of AI safety, such as protecting intellectual

property, ensuring transparency, and implementing anti-discrimination protocols. In addition, there are provisions specific to China's context that AI service providers must follow. These include aligning with socialist values and avoiding the creation of content that incites opposition to the State. Furthermore, these companies must obtain a license to offer generative AI services to the public in China. If the services provided by a company have the potential to influence public opinion or mobilize people socially, a security assessment must be carried out. It is compulsory for companies that offer generative AI services in China to uphold state authority, prevent the spread of separatist thoughts, maintain national unity, support economic and social stability, and ensure that their products align with the nation's socialist principles. China is also enhancing its administrative frameworks to rapidly and effectively introduce new laws for AI governance. This approach enables the country to swiftly update its regulatory policies in response to the evolving applications of AI technology ("How Does China's Approach to AI Regulation Differ from The US And EU?", 2023).

The European Parliament voted in favor of adopting the Artificial Intelligence Act, which, in its current form, prohibits or restricts some high-risk applications of AI (Fazlioglu, 2023). The first attempt to pass a horizontal regulation for AI is represented by the draft AI legislation. The specific application of AI systems and the risks that come with it are the main topics of the proposed legal framework. The Commission wants to classify AI systems according to a "risk-based approach," which would include various criteria and obligations for each system. It also wants to establish a definition of AI systems in EU law that is technology neutral. Certain AI systems that pose "unacceptable" risks would not be allowed. In December 2021, the Council agreed on the general position of the EU Member States. In June 2023, parliament voted on its position. The European Union lawmakers are now beginning negotiations to finalize the new legislation that includes significant changes to the Commission's proposal. The new proposal includes a revised definition of AI systems, an expanded list of prohibited AI systems, and obligations placed on general-purpose AI and generative AI models like ChatGPT (Madiega, 2023).

Government investment in AI

Many governments around the world have acknowledged the importance of AI and have allocated significant funds to promote AI development. These investments are often a part of broader national programs that support innovation, competitiveness, and economic growth. The United States has been leading globally in AI investment since 2013, with a total amount of around $250 billion in 4,643 startups. This trend of investment is on the rise. There were 524 new AI firms founded in the United States in 2022, and they received $47 billion in capital from the private sector. On the other hand, China recorded the highest average corporate investment per AI startup in 2022. Its 160 newly founded AI startups received an average of $71 million each (Kennedy, 2023).

In the US, the National Science Foundation (NSF) has launched a $140 million investment to establish seven new National Artificial Intelligence Research Institutes (AI Institutes). These institutes aim to develop innovative methods for cybersecurity, contribute to creative approaches to climate change, broaden our knowledge of the brain, and use AI capabilities to improve public health and education. They will also advance fundamental AI research that promotes ethical and

dependable AI systems and technologies. These AI Institutes are expected to proactively address potential risks and undesirable outcomes associated with AI and promote diversity within the US AI workforce (NFS, 2023).

In China, the government is actively fostering the growth of its AI industry, aiming to build an AI sector valued at $150 billion by 2030. Complementing government efforts, the Chinese private sector is also significantly engaged in AI development. For instance, Baidu, a major internet company, has been pursuing an "AI first" strategy since it established the Institute for Deep Learning in 2013 and opened its Silicon Valley AI Lab in 2014. In January 2018, the Beijing Frontier International AI Research Institute was founded, led by Kai-Fu Lee from Sinovation Ventures. In addition, various cities in China, including Beijing, Shanghai, Hangzhou, Zhejiang, and Tianjin, are implementing local AI initiatives. These include Shanghai's plan to create a special fund for AI development and Hangzhou's establishment of an AI industrial park, accompanied by a fund of around $1.5 billion to support it (Mou, 2019).

The European Commission, through the Horizon Europe and Digital Europe programmes, aims to invest €1 billion annually in AI. This initiative is expected to attract further investments from the private sector and Member States, with the goal of achieving a yearly investment total of €20 billion throughout the digital decade. In addition, the Recovery and Resilience Facility has allocated €134 billion for digital advancements. This substantial funding is set to significantly transform Europe's digital landscape, enabling it to elevate its goals and emerge as a global frontrunner in the creation of advanced, reliable AI (A European approach to Artificial Intelligence). In December 2023, the Commission approved the revision of the Digital Europe work programs for 2024, which included a fund of €762.7 million to enhance digital solutions for the benefit of citizens, public administrations, and businesses (EU to invest more than €760 million in digital transition and cybersecurity).

2.3.2.2.3 Society

Traditionally, Facility management (FM) has been considered to be cost-centric rather than value-driven (Facilio, 2020). However, modern consumers have higher expectations for connected services and the space experience. As a result, FM is becoming increasingly tech driven. The built space has a direct impact on the productivity of the workplace and the well-being of occupants. This has resulted in property value improvement that offers an enhanced user experience (Tucker et al., 2008) and an advancement of constructing and upgrading existing spaces by implementing and utilizing tech-enhanced services that bring in revenues for their facilities (Facilio, 2020). In addition, it saves overall time and money by utilizing several automated processes (Lau, 2013).

Urban migration is becoming more and more popular. It is expected that over six billion people will live in cities and surrounding areas by 2050. Therefore, in the near future, improving the economic, social, and environmental well-being of individuals may depend critically on the autonomous and intelligent management of cities. Most human life is spent in buildings, which account for the majority of the world's power consumption and CO2 emissions. As a result, occupants play an important role since they are the recipients of the indoor services provided by buildings' installed electrical appliances, which are in charge of creating comfortable surroundings. It is necessary to have a

building management system that can address energy efficiency standards while also taking user comfort levels into consideration in real time (Moreno et al., 2014). AI's broad potential and capacity for autonomous operation are key factors in the field's fast growth in the urban planning domain. AI systems are now a part of the contemporary infrastructure, despite the fact that the general public still tends to view AI as a fantastical concept best left to science fiction (Farzaneh et al., 2021). AI is ideally equipped to use real-time data to flexibly regulate urban energy systems (Alahakoon et al., 2015). Big data and AI are used to optimize end-use energy efficiency and demand response, which lowers on-site energy costs (Allam et al., 2019). The importance of facility user behavior drives new strategies that result in the collection of more staff data; however, obstacles have ultimately been placed in the way of big data obtained from individuals due to worries about personal integrity (The Economist, 2017). The new General Data Protection Regulation (GDPR) reflects this concern and imposes further limitations on organizations conducting FM research, such as those examining satisfaction among office workers. This shares similarities with medical studies (Rumbold and Pierscionek, 2017).

Other users who have driven the AI adoption are people who work for FM. The fact that facility managers spend a lot of time on unproductive duties like visualizing models, searching for information, and validating various bits of data are the reasons for implementing AI in facility management. As a result, participants in the facility management sector appear committed to integrating digital technology, implementing new procedures, and emphasizing effective management throughout the building life cycle, according to global technological trends. A digital boom is occurring in this industry as a result of the incorporation of new ideas, concepts, and methods. However, until now, businesses in the facilities management industry are not highly technologically advanced (Pedral Sampaio et al., 2022). Although facility managers have the potential to contribute to the achievement of sustainable development goals, Kwawu et al. (2011) emphasized that for them to fully seize the opportunities presented by incorporating sustainability principles into fundamental Facility Management business strategies and operations, they will need to acquire the necessary knowledge and skills.

2.3.2.2.4 Academia

Shaping future FM has been a priority for education, research, and practice development from the beginning of the 1980s. From the perspective of academia, facilities management needs to be considered an applied subject of study with a significant emphasis on the professional advancement of FM. A combination of theoretical effort and practical application has led to the introduction and development of models, systems, and techniques for managing many diverse activities within FM (Jensen, 2019). According to the systematic review of AI applied to Facility Management by Pedral Sampaio et al. (2022), there has been an increase in the research related to the application of AI in Facility Management in recent years. Over 77% of the papers under consideration were published during the last five years. It was also noted that the papers that are currently published are much more specific and concentrated on the application of new technologies and techniques, whereas the earlier publications were broader and more theoretical (Pedral Sampaio et al., 2022).

Researchers and FM experts are considered to benefit from the partnership in terms of increased communication, better dissemination to pertinent target groups, validation and enhancement of content, and shared expertise and resources. However, both FM associations and organizations have limited involvement in R&D projects and don't have close contact with researchers (Jensen et al., 2023). According to Klungseth et al., (2022), there is a significant research gap on FM standards. In 2011, two workshops on this subject were held during a Nordic conference on FM research, with scholars and practitioners in attendance (Alexander, 2012). Among the conclusions drawn from these workshops was the necessity of research and practice working together effectively for FM to grow as a field and a profession and to create a strong foundation of a reliable knowledge base. The practitioners in the workshops discovered that the current research often lacked relevance to real-world tactical and operational difficulties. Therefore, better communication strategies were necessary to close the gap (Alexander, 2012). Besides that, universities' incentive systems place a great deal of emphasis on scholarly publications; scholars who participate in standardization efforts are rarely acknowledged or given awards. Thus, there is little incentive for researchers to take part, and the primary motivations for those who do are their personal and professional goals. As a result, FM associations and practitioners ought to encourage researchers' participation in standardization by interacting with them more frequently and sponsoring their involvement in standardization (Jensen et al., 2023).

The collaboration between EuroFM, IFMA, and other national and international FM networks reflects the relationship between education, research, and practice that has driven FM's growth in many countries in recent years (Bröchner et al., 2019). Early in the 1990s, IFMA and EuroFM organized FM conferences that created a platform for close cooperation between industry and academia. Students, educators, and researchers collaborate with professionals in the knowledge triangle of FM research, practice, and education. They work with actual instances and problems from practice. This interaction forms the basis of the learning process, providing opportunities for the creation and testing of new models and solutions for the FM operations of the future. This brings up new commercial prospects and facilitates skill development and knowledge acquisition of novel ideas, models, and practical solutions. In order to advance FM as a topic of study and a professional discipline, master's and doctoral studies are required. Studies pertaining to actual issues and difficulties facing FM, as well as initiatives built around partnerships with the FM sector (Roper, 2017).

2.3.2.2.5 Anchor Institution IFMA

The International Facility Management Association (IFMA) was established in 1980 and is regarded as the largest and most influential global association for FM professionals. With over 24,000 members spread across more than 100 countries, IFMA supports a thriving community of FM experts. The organization is dedicated to shaping the future of the built environment sustainably, with a vision to "make the world a better place". Its mission is to empower FM professionals to perform at their best by advancing their collective expertise, value, and professional development (IFMA).

IFMA offers a range of services to its members, including certification programs, research, educational programs, and conferences. The organization's official journal, FMJ, is a bimonthly publication written for facility professionals (IFMA).

IFMA's key activities in facility management include the following:

Training

IFMA is a leading provider of training and credentials for professionals in FM. These training programs are specifically designed to help FM professionals develop their skills and knowledge to succeed in their careers. IFMA provides a variety of training options, including online courses, webinars, and in-person training sessions (IFMA).

Events & Networking

IFMA fosters information exchange in the FM industry and academia through events and networking. IFMA hosts a variety of events throughout the year, including online and in-person events. These events provide facility management professionals with opportunities to network, learn from experts in the field, and stay updated on the latest trends and developments in facility management. IFMA's event, World Workplace, is held annually and is the largest gathering of FM professionals worldwide. Besides that, IFMA's online forums serve as a platform for FM professionals to connect with one another, share ideas, and seek advice (IFMA).

Research & Benchmarking

IFMA supports the industry with research and benchmarking data to help facility managers make informed decisions. Their research covers a wide range of topics, including sustainability, workplace strategy, and technology. IFMA also provides benchmarking data to help facility managers compare their performance against that of their peers (IFMA).

Overall, IFMA provides a range of services and activities to help facility managers develop their skills, stay updated on the latest trends and developments, and connect with other professionals in the field. Besides that, IFMA also fosters the connection between industry and academia and commits to the sustainable goal of the government.

2.4 Facility Management's New Tech Opportunities

2.4.1 Emerging Trends and Technologies

Driven by today's multiple trends and disruptive technologies, the field of facility management is undergoing profound changes. The latest white paper from the International Facility Management Association (IFMA) summarizes six key trends that are redefining the industry: PropTech, AI vs generative AI, tackling climate change, circular economy, environmental, social and corporate governance (ESG) reporting, and health and wellbeing (" Evolution Is Never Finished: Insights from IFMA'S Emerging Topics Working Group on How Six Key Topics," 2023).

We also refer to the latest market research reports and industry summits that portray this transformative era of dynamic trends and important challenges in this way. New research by Fortune highlights the current and future surge in demand for cloud-based FM systems. It shows that the Facility Management practices to technology integration and efficient (Facility Management, Market Size, Share | Growth Report [2030], property-and hit large reserves - b). Moreover, the exponential growth in real estate investments is also driving the development of smart buildings. Intelligent building through the Internet of things (IoT), artificial intelligence and the combination of forecasting techniques reshaped the FM areas (Facility Management, Market Size, Share | Growth Report [2030], property-and hit large reserves - b). Jones Lang Lasalle (JLL) highlights how predictive technology can not only help FM cut costs but also have a positive and far-reaching impact on global sustainability initiatives. AI is a proactive tool to optimize costs and manage the environment. ("How AI Is Influencing Facilities Management," 2023). Speaking at the inaugural Technology Summit of the Property Council of Australia in Sydney, Phil Rowland from CBRE highlighted the potential of AI technology to increase productivity, create inclusive built Spaces and reduce environmental impact. This view of his echoes JLL's emphasis that the utilization of AI-driven forecasting techniques can reduce costs and promote the sustainability of FM practices.

Looking across the contemporary landscape of facility management, we see: a growing demand for integrated technology solutions; the need for sustainable development; and the need for more flexible strategies amid changing workplace dynamics. As the FM industry addresses these trends and challenges, the integration of AI technologies is undoubtedly a key element in achieving progressive, efficient, and sustainable facility management practices. Therefore, the following part of the paper focuses on AI applications and their integration in the field of facility management.

2.4.2 AI Applications and Integration

Enhancing Productivity and Operation

Artificial Intelligence has a big influence on productivity and business processes in the FM. AI releases human workers from repetitive and routine duties, freeing them up to concentrate on more creative, analytical, and strategic work (Vincent, 2021). Through the application of AI, systems can also better understand the data that is already available, which leads to more accurate information and better decisions. By carefully analyzing the data produced by consumer interactions and business processes, businesses can find solutions to improve operational efficiency and maximize their goals (Jöhnk et al., 2021). AI can also improve how people engage with technical systems. Systems that use natural language processing can comprehend and reply to human queries in common language, helping with a variety of tasks like customer service and technical support (Nurlia, 2023). Many companies have integrated artificial intelligence technologies into their everyday activities, utilizing AI-driven virtual assistant tools to assist customers. Besides that, AI chatbots serve as efficient solutions for automating routine tasks such as managing tenant requests, coordinating maintenance schedules, and offering immediate updates on work orders. By assigning these responsibilities to AI, Facility Managers can free up significant time, enabling them to concentrate on strategic planning and critical decision-making that contribute to the success of their organization (Carron, 2023).

Moreover, many studies have shown that when people feel safe, they're more productive - whether it's at work, at home and in life (Collett, 2023). AI technology has tremendous potential for enhancing building occupant safety and security through its ability to work with vision systems and sensors (Baduge et al., 2022). Liu et al. (2001) discovered new concepts and technology designed to boost the capability of fire protection systems for smart buildings. The study described the benefits of a fire sensor system that tracks and detects flames using video cameras, computers, and AI. Chooch.ai, an AI-based firm, offers readily available AI algorithms that can detect fire and smoke and can be installed on edge computers in a matter of days (Chooch, 2023). Due to the fact that the enormous volume of image data can be handled by deep learning algorithms with exponential efficiency, Kim et al. (2020) suggested a pedestrian identification model based on deep Convolutional Neural Networks (CNN) for the classification of pedestrians from the input images.

Organizations need to incorporate AI into their company's strategies effectively in order to achieve lasting productivity and operation enhancement. In other words, the technology should not only automate operations but also contribute to the generation of new insights and better value (Shaw et al., 2019).

Energy Efficiency

Buildings consume approximately 40% of all the energy produced worldwide. An enormous amount of this energy is used to maintain the comfort of the building's occupants. Because existing systems depend on sensors that run pre-programmed software that is incapable of adjusting to changing conditions, they are inefficient (Baduge et al., 2022). Many AI-based solutions are being used to improve indoor thermal comfort. Ngarambe et al. (2020) reviewed the state-of-the-art thermal comfort prediction models utilizing various machine learning algorithms and their application in building control systems for energy conservation. An overview of the application of four primary machine learning techniques - ANN, support vector machines, Gaussian-based regressions, and clustering - for forecasting and enhancing building energy performance has also been presented by Seyedzadeh et al. (2018).

Several fascinating AI-developed techniques for energy optimization are explored. Mehmood et al. (2019) underlined how AI, when paired with big data, may significantly improve the cost-effectiveness and energy efficiency of structures meant to give inhabitants a comfortable indoor living space. Fan et al. (2017) utilized deep learning to improve the performance of building cooling load prediction. In order to maximize energy usage and comfort. Verma et al. (2023) developed a design for a multi-agent topology-based building management system that uses AI to control temperature, illumination, and CO2 concentration within a building. Pham et al. (2020) proposed a Random Forests (RF)-based prediction model to forecast hourly short-term energy consumption in several buildings. One Taikoo Place, completed in 2018, is the first AI-enabled building in Hong Kong. It has Arup Neuron, an AI smart building console that uses advanced data analytic capabilities, machine learning, and predictive maintenance algorithms to conserve energy (Baduge et al., 2022).

Predictive maintenance

AI algorithms, by analyzing historical data, can detect patterns and trends that signal potential equipment failures or maintenance needs more effectively than conventional traditional maintenance scheduling (Carron, 2023). Effective maintenance practices can extend the life of building components and reduce building maintenance expenditures, which make up over 65% of yearly facility management spending (Eastman, 2011). In contrast to reactive or preventive maintenance, predictive maintenance - also referred to as condition-based maintenance - tries to identify early failures and eventual degradation based on the identification of patterns in component states using historical data so that prompt action can be executed (Mobley, 2002). A variety of machine-learning methods, including Markov chains, SVM, and ANN, can be used to predict the state of construction components (Baduge et al., 2022). However, as not all buildings generate big enough data sets for training, deep learning is not suitable for every issue or building (Baduge et al., 2022).

Circular Economy

AI has the potential to significantly speed up the circular economy shift, particularly in the area of reuse, repair, and recycling (Baduge et al., 2022). The circular economy is a comprehensive strategy for sustainability. Systems and products in a circular economy are created to eliminate waste by enabling the recovery and reuse of all resources at their maximum value at all times (Saunders, 2023). Organizations can leverage the applicability of clustering algorithms to improve resource sharing through digital sharing platforms that encourage Reuse. Time series analysis can be used to discover recurring trends or predict events that will require Repair in the future (Yip et al., 2014). AI makes it feasible to automate the recycling of waste, which is more cost-effective and results in better material recovery than traditional approaches (Baduge et al., 2022). AI can handle numerous ideas and suggest the ones that best fit the circular design requirements, which helps to further reduce complexity (Huang, 2021). Reuse, resale, repair, or recycling recommendations can be provided, and condition evaluation can be automated with machine vision to maximize value preservation. Demolition engineers may be able to estimate demolition materials more quickly with the use of deep neural networks (Baduge et al., 2022). Furthermore, with AI implementation, robotic systems will be able to perform multiple tasks at once, including sorting. In certain situations, the robots are used in place of human sorters, find usage in previously unsortable areas (such as construction site trash, maritime waste, and hazardous waste), and/or provide automatic inspection and improvements (e.g. in the case of plastics) (Baduge et al., 2022).

Business Model Innovation

Businesses need to undertake a significant organizational change to develop AI capabilities and integrate them into the business model to remain competitive and gain benefits from AI (Iansiti & Lakhani, 2020; Porter & Heppelmann, 2014). In order to ensure value delivery, capture, and competitiveness, this new business model requires a revision of the logic surrounding the fundamentals of how AI technology is integrated into value offerings and how it interacts with individual work, organizational functions, and the various business processes (Iansiti & Lakhani, 2020). AI technology can offer numerous advantages for business models, benefiting customers by reducing expenses, improving service quality, boosting productivity, and enhancing the efficiency of

deliveries (Davenport & Ronanki, 2018; Iansiti & Lakhani, 2020). AI-driven business models, through their ability to increase scale, broaden the scope, and enhance learning opportunities, can investigate creative approaches to create, deliver, and capture value, thereby enhancing competitiveness (Iansiti & Lakhani, 2020).

3. Methodological Framework

As a discipline, Facility Management has developed rapidly since its emergence. It is closely related to people's living and working environment, so it has gained more and more attention. In recent years, the rise of artificial intelligence has had a huge impact on various industries around the world, and FM is no exception. This study uses an exploratory research approach to deeply explore the integration of AI in the field of FM, aiming to propose strategies to enhance AI implementation in the field of FM through the perspective of the four-helix model. To achieve this, the study was guided by three main questions:

1. What are the barriers and drivers for Facility Management to adopt AI?
2. How is the ecosystem of Facility Management influencing AI integration from a quadruple helix perspective?
3. How to strengthen ecosystem linkages to foster AI integration in FM?

To address these issues, a qualitative research approach is used in this paper. These included interviews with seven experts with different knowledge backgrounds and positions in the FM industry. This research approach helps to obtain practical insights and recommendations. This helps to shape the future trajectory of the FM industry.

ID	Candidate Position	Sex	Duration	Date
C1	Co-founder	M	45 mins	31/10/2023
C2	Managing director	F	60 mins	13/11/2023
C3	Head of Commercial Excellence	M	60 mins	20/11/2023
C4	IT specialist	M	60 mins	20/11/2023
C5	Product and innovation officer	M	60 mins	23/11/2023
C6	Author, Keynote speaker, Entrepreneur	M	65 mins	24/11/2023
C7	Chair, Managing director, Co-founder	M	65 mins	30/11/2023

Table 1: Interview information

3.1 Research Context

Exploratory research is a widely used method when no research is available on a specific topic or when available research is limited. This type of inquiry is more conducive to identifying potential research questions and hypotheses. This sets the stage for a more detailed investigation in future research. Swedberg (2020) emphasized that exploratory research is usually used in the social

sciences to enhance the understanding of a specific phenomenon or behavior. Yin (2011) believed that qualitative research was a flexible and iterative process, involving a wide range of data collection methods, including interviews, observation and document analysis.

In this study, the researchers chose to use qualitative data collection methods to conduct exploratory research and conduct expert interviews in a semi-structured manner. Using the interview method, we can deeply understand the attitude, behavior and experience of the respondents. Overall, qualitative research is considered to be an effective means of exploring complex social issues by providing detailed and in-depth information that facilitates insightful analysis. The goal of this study lies in gaining insight into the views, experiences and knowledge of individuals in government, industry, academia and society. Continuous interviews through targeted sub-questions were essential to obtain comprehensive, rich and detailed information. Qualitative methods were seen as the recommended and best option for reviewing this research, allowing researchers to discern subtleties and identify emerging patterns, themes, and trends inherent in the topic.

3.2 Research Questions

This study examines the application/integration of AI in FM from a quadruple helix perspective, exploring the interrelated roles of academia, industry, government, and society. The aim is to reveal detailed insights into how these four pillars synergistically contribute and facilitate the successful integration of AI in facility management practices. By investigating the multifaceted dynamics among these stakeholders, the study aims to provide practical implications for real-world implementation. This will be done by addressing the following research questions:

1. **What are the barriers and drivers for Facility Management to adopt AI?**

The primary purpose of this research question is to systematically investigate the opportunities and challenges associated with the adoption of artificial intelligence (AI) in the realm of Facility Management. By addressing this question, the study aims to shed light on the potential benefits and obstacles that organizations within the field may encounter when integrating AI technologies.

2. **How is the ecosystem of Facility Management influencing AI integration from a quadruple helix perspective?**

The purpose of this research question is to delve into the intricate dynamics of the Facility Management ecosystem and its impact on the integration of AI from a quadruple helix perspective. By exploring the collaborative roles of academia, industry, government, and society in this context, the study seeks to uncover the nuanced relationships and influences shaping the adoption of AI in FM. The inquiry aims to provide a comprehensive understanding of how these diverse stakeholders interact and contribute to the successful incorporation of AI technologies.

3. **How to strengthen ecosystem linkages to foster AI application/integration in FM?**

The purpose of this research question is to investigate strategies and approaches for enhancing the linkages within the ecosystem to facilitate the integration of AI in FM. By addressing this question, the study aims to identify and analyze the mechanisms and initiatives that can strengthen connections between various stakeholders involved in FM and AI integration. The research aims to provide practical insights into fostering collaboration and synergy among academia, industry, government, and society, thereby contributing to a more cohesive and supportive environment for the effective implementation of AI technologies in Facility Management practices.

3.3 Methodology Approach

The study employed semi-structured interviews as the primary data collection method to gain key insights on how the various components of the Quadruple Helix model (government, industry, academia, and society) synergistically influence and support the integration of AI in facility management. By deeply exploring the complex interrelations between these stakeholders. The study aims to provide practical recommendations for practical implementation.

The sample population was selected based on factors such as the candidate's country of residence, organizational role and experience. The initial stage of the interview process consisted of asking introductory questions to obtain information about the profile and the role of the organisation. All participants were carefully selected through personal relationships established through LinkedIn and the researchers. The researcher connected with the respondents via email and provided a brief introduction to the study, an overview of the study, and interview questions. Seven respondents were ultimately identified as the source of data collection in this study.

3.4 Data Collection

Due to the rapid development of digital communication technology, this study adopted online platforms such as Google Meet and Zoom for multiple rounds of interviews. The respondents were distributed entirely outside Hasselt, Belgium, with some of them residing in other countries. Therefore, the adoption of online meetings is a necessary choice to ensure the continuity of interviews. Although face-to-face interviews are believed to establish an open atmosphere and interpret non-verbal cues (Ritchie, 2013), online interviews have also been shown to produce credible and effective results. Throughout the data collection phase, consistent attention was given to relevant contemporary scholarly research in addition to the interview data.

In pursuit of comprehensive in-depth insights from each respondent, inclusive and semi-structured interview methods were used in this study. This approach enabled respondents to express their thoughts and opinions according to the questions of the researchers. The interviews began with introductory questions to understand the role and identity of the respondents, emphasizing the importance of placing their views in context. After a series of preliminary and general questions, the researcher turned to deeper and specific questions to reveal the insights and understanding of the respondents. The interview questions were constructed according to the research objective system, and each question was further broken down into detailed sub-questions, which facilitated a

comprehensive exploration of the topic. To facilitate meaningful participation and preparation, respondents received questionnaires prior to the interview, enabling them to review and prepare responses to questions asked by the researchers in advance.

3.5 Data Analysis

As Sutton et al. (2015) highlighted, it was necessary to transcribe the recordings before processing, organizing, and interpreting the interview content. In qualitative interviews, it is extremely important to understand the perspective of the interviewees and grasp their views. In the data analysis, we strive to avoid the subjective interpretation of the researchers and be 100% faithful to the respondents. The goal was to ensure that participants' voices could be understood by others and provided rich information (Sutton et al., 2015). Topic coding, also known as topic analysis, is used to identify the basic structure of words and phrases in a text. The core of coding is to identify and define the text or data object parts that embody similar theories or descriptive ideas (Gibbs, 2007). The importance of this procedural step is that it enables the researcher to construct thematic conceptual frameworks for data analysis.

Researchers can categorize and organize the material by linking various paragraphs to specific terms, which can help identify patterns and formulate relevant conclusions. Specifically, coding involves a systematic analysis of the data to identify themes, patterns, and correlations and to classify them. This approach requires researchers to carefully evaluate and analyze data, identifying passages that summarize specific concepts or ideas. Once identified, these paragraphs are assigned a unique identifier or label that serves as a reference point for all text or data related to the same idea or concept.

Thus, the data analysis process consisted of three consecutive steps. First, a text reading was conducted to mine for general information, followed by a deeper exploration of the information provided. Subsequently, the researchers compressed and summarized the text through coding, using concise phrases to represent the themes of the text. Due to the large number of codes in this paper, to ensure the continuity of readers' reading, the coding tree table will be presented before each chapter.

4. Findings

Facilities management is attracting more and more attention worldwide. It goes deep into every aspect of people's daily life. FM contains eleven core competencies. It is the link that coordinates the different modes and stages of operation among facilities. Integration with artificial intelligence (AI) is key to driving multifaceted innovation and operational efficiency in facility management (FM). This study mixes a literature review and in-depth interviews with seven FM industry experts in an attempt to examine the current practice of AI integration into FM in the framework of a quadruple helix model. Our findings shed light on the urgency and importance of AI adoption in FM, exposing the enablers and barriers to a seamless integration of AI with FM.

There is a high degree of agreement among industry experts on the critical role of AI in enhancing FM operational capabilities. All the experts clearly recognize the transformative potential of artificial intelligence. To varying degrees, they emphasized AI's ability to optimize resource allocation, enable predictive maintenance, and improve overall operational efficiency across the FM domain. On this basis, the experts also pointed out the key enablers of AI in FM practice, while also revealing the obstacles encountered in reality.

Together with our interviewees, we analyzed current FM dynamics through the lens of a quadruple helix model – combining the four helices – government, academia, FM industry, and society-to explore intricate connections and search for opportunities to promote development. Experts unanimously stressed that only by strengthening academic and industrial cooperation can innovation and knowledge transfer be accelerated. They also argue for strong industry regulations. In addition, some experts stressed the importance of government leadership in promoting AI convergence. Increasing end-user awareness about carbon neutrality, sustainability, and AI technologies was also a focus of discussion among the experts.

In view of the complexity of the FM ecosystem, the advice of experts can be used as a guide and reference for the development of the industry. Collectively, they call for interdisciplinary collaboration to steadily integrate technological developments with sustainable practices. In addition, they emphasize the critical role of a suitable policy framework. These frameworks can promote innovation while ensuring that AI deployment within FM is ethical.

STEP 1	STEP 2	STEP 3
RQ1: What are the barriers and drivers for Facility Management to adopt AI?	4.1 Importance of AI Integration	4.1.1 Inevitable Evolution
		4.1.2 Cost Reduction & Efficiency
		4.1.3 Enhanced Occupant Experience
		4.1.4 Energy Saving, Emission Reduction & Decarbonization Focus
	4.2 Enablers for AI Integration in FM	4.2.1 Big Data in Facility Management
		4.2.2 Technological Collaboration
		4.2.3 Large Service Providers are Enabling the Trend
		4.2.4 Learn Good Practices from Other Sectors
	4.3 Barriers for AI Integration in FM	4.3.1 Legacy Technology
		4.3.2 Reluctance to Change
		4.3.3 Split Incentives
		4.3.4 Change Management and Staffing Model Concern
		4.3.5 Data Management and Privacy
		4.3.6 Skills Gap

Table 2: Coding Tree RQ1

4.1 Importance of AI Integration in FM

In today's world, Artificial Intelligence (AI) is experiencing unprecedented popularity. The impact of using Artificial Intelligence (AI) is changing the way people interact with information and technology. The integration of Artificial Intelligence (AI) is no longer just an option, it's a strategic requirement. The application and integration of Artificial Intelligence (AI) enables enterprises to remain competitive and meet the growing expectations of stakeholders for Facilities Management (FM).

4.1.1 Inevitable Evolution

The integration and application of artificial intelligence (AI) in facility management (FM) undoubtedly marks the inevitable progress of the industry technology landscape. While aware of this inevitability, the current state of the FM field reflects the nascent stage of adaptive AI application and integration. It requires the joint efforts of all sectors of society to achieve substantial progress. Despite the obvious certainty of the integration of AI and FM, it is still in its infancy at this stage. The FM industry still needs a lot of groundwork and strategic effort to realize the full potential of AI. The FM industry has taken a relatively cautious stance when discussing the future of developing a symbiotic relationship between technology and facility operations centered on AI.

> "We will have no other choice. Artificial Intelligence is something that is integrating or starting to be integrated, in many ways in our society and life: in buildings, in managing and operating buildings. And it is almost a natural evolution, I would say, all our buildings and cities are becoming much more digitized, smart, etc." (C2)

> "…especially also the AI, everybody is looking at it, and to incorporate it in the solution." (C6)

This stance underscores AI's pervasive influence, marking an organic progression integrated into building management, aligning with the global drive for efficiency, sustainability, and connectivity within the built environment.

Moreover, (C2)'s perspective emphasizes the inevitability of AI's integration, not as a mere choice but a trajectory demanded by the digitization shift.

> "It's an inevitable evolution, which will, let's say, be beneficial to the facility managers and the users of buildings, facilities, etc. So, I think that is, for me, essential." (C2)

The integration of architecture and urban landscape with AI affirms the potential of AI technology to improve operational efficiency and user experience in FM practices. This point is consistent with the views of industry professionals. The continuous development of artificial intelligence in FM is not an isolated phenomenon, but in line with the general trend of global technological progress. Take OpenAI's ChatGPT, an innovation that marks the rapid rise of artificial intelligence. It will bring about great changes in all fields. The continuous evolution of AI technology has created opportunities and a sense of urgency for all industries, prompting industries and individuals to actively integrate and apply AI. In FM, the role of AI reflects the paradigm shift triggered by technological assimilation. This trend is not only a product of industry developments, but also reflects the overall shift of society towards a digital future. The consensus view of the interviewed experts on the trajectory of FM demonstrates the inevitable intertwining of AI technology and the operational structure of facilities.

4.1.2 Cost Reduction & Efficiency

Research on the integration of AI with facility management (FM) has revealed its critical role in cutting costs and improving operational efficiency. Expert views show the profound impact of artificial intelligence on the industry to reduce costs and increase efficiency. The integration of AI technologies is seen as a catalyst that promises to transform FM practices across the board, especially in terms of cost reduction and efficiency gains.

In discussing cost reduction, interviewee underscores the significance of leveraging data to optimize facility operations.

> "When it comes to how to use data to better the facility, the one is obviously reducing the operating cost. So that's important to the FM professional, obviously." (C1)

This viewpoint accentuates the pivotal role of data-driven decision-making in driving down operational expenses within FM domains, signifying AI's potential in refining cost-related strategies.

Furthermore, the validation of AI's cost-saving potential is articulated by referencing a study by Carnegie Mellon University.

> "...that's the use of AI and it's been validated. In an academic outreach by Carnegie Mellon University, Vidya New Carnegie Mellon, and they have done an analysis of that somewhere in the neighbourhood of saving a quarter million dollars a year per building." (C1)

This validation quantifies AI's impact, showcasing its ability to deliver substantial cost savings, thereby validating its adoption as a strategic asset for FM professionals seeking to optimize expenses.

Shifting focus to efficiency enhancements, interviewee underscores AI's broader applicability in refining internal processes and operations.

> "...when you go to look at efficiencies, improvement of efficiencies very clearly is that we have an open look into how we can deploy that in terms of very simple things as well, like translations and stuff we serve, let's say open globally." (C5)

This perspective highlights the versatility of AI to improve operational efficiency, transcend language barriers, and optimize global outreach, showing its potential to simplify all aspects of FM operations. The fusion of these expert insights highlights the multifaceted role of AI in FM, heralding a paradigm shift in how cost-reduction strategies and operational efficiencies are perceived and implemented in facility management practices.

4.1.3 Enhanced Occupant Experience

The integration of AI into FM not only improves operational effect, but also enhances user experience. Experts believe that AI has the potential to transform user interactions within buildings and create personalized, comfortable, and efficient environments. The deep combination of AI and FM will redefine the residential experience and optimize the built environment to meet the needs of different users.

The incorporation of AI technologies, as highlighted by (C2), profoundly impacts user experiences within buildings and environments.

> "AI can really make life easier for users and bring an enhanced experience of buildings and environments. So I see the benefits of integrating AI in certain aspects, in buildings, I definitely see that. And I think users see that as well." (C2)

This perspective emphasizes AI's role in facilitating user tasks, crafting personalized environments, and ultimately enhancing overall user satisfaction, positioning AI as a key determinant of occupant experience enhancement.

Another interviewee further elucidates the overarching vision intertwining AI and FM, emphasizing the goal to intelligently impact built environments globally.

> "...our vision is to intelligently impact their built environments anywhere in the globe…. the two are improving the occupants' experience, no matter if it's office or it's, you know, if it's an Office tenant or retail shopper or a resident in multifamily." (C3)

This expansive vision signifies AI's role in transcending building types and tenant profiles, aiming to enhance experiences across diverse occupant categories, reflecting its pivotal role in shaping a universally enriched user experience paradigm.

Moreover, (C6) delves into the practical implications of AI integration by highlighting its impact on employee experiences. They emphasize the deployment of IoT sensors to measure occupant presence, allowing AI-informed HVAC systems to adapt automatically, optimizing comfort levels.

> "For example, it's about the employee experience. Because it's going to measure the buildings are filled with sensors with IoT sensors. It's going to measure where the people are, and the HVAC system is going to adapt automatically. So their AI is involved." (C6)

This shows the substantial impact of AI on user comfort. Personalization and optimal environment adjustment through AI algorithms can effectively enhance user experience in FM environments. These points were highlighted by several experts. They unanimously affirmed that artificial intelligence plays a key role in FM. In particular, the potential of AI to shape rich and personalized occupant experiences in different built environments is highlighted.

4.1.4 Energy Saving, Emission Reduction & Decarbonization Focus

In the realm of Facilities Management (FM), the integration of Artificial Intelligence (AI) resonates as a transformative catalyst, aligning with the European Union's (EU) stringent Environmental, Social, and Governance (ESG) objectives. As discussions veer towards sustainability, experts highlight AI's multifaceted role in addressing critical challenges related to energy consumption, emission reduction, and decarbonization within the built environment. Three expert insights highlight the key role of artificial intelligence in solving energy consumption, emissions reduction and decarbonization issues in FM, demonstrating its potential to align FM practices with ESG goals and promote sustainable building practices.

One of the experts emphasizes the pressing need for decarbonization, particularly within the EU's stringent environmental targets. This accentuates the necessity of AI integration as a strategic imperative to combat the substantial carbon footprint originating from buildings, thereby aligning FM practices with the EU's decarbonization goals.

> "And then the third piece, which is much more predominant in the EU where you guys are than here in the States, is around 'decarbonization'... We aren't good at decarbonizing buildings which represent almost 40% of the annual carbon emissions." (C1)

Another interviewee delves into AI's role in energy management within buildings, highlighting its capacity to profile and optimize energy consumption patterns. This perspective underscores AI's capability to analyze energy usage patterns, enabling informed decisions aimed at reducing energy footprints and enhancing building operational efficiency.

> "Now if you basically move into use cases, I will say there are some areas which seemed to be interesting. One of them is probably into energy management and profiling of buildings…In terms of energy footprint reduction, we see some potentially interesting cases where basically AI will profile, it's kind of fun." (C5)

Moreover, the discourse shifts towards the profound impact of AI on sustainability endeavours, as articulated by (C6). They draw a direct link between ESG goals and AI-enabled energy management, asserting,

"...talk about ESG and everything about sustainability. And if you can say, because you know 1/3 of CO2 production comes from buildings. So, this is really important to know. Okay, if you apply AI, you can make sure that your energy consumption and everything about us…" (C6)

This viewpoint accentuates AI's potential in curbing CO2 emissions by optimizing energy usage in buildings, aligning actions with the core principles of ESG sustainability.

4.2 Enablers for AI Integration in FM

When discussing the importance of integrating artificial intelligence (AI) technologies into facility management (FM), in addition to understanding its potential, it is equally important to examine the key factors that facilitate such integration. These "push factors" are fundamental to the effective application of AI technology. In the following discussion, we will delve into six key elements that are not only key to supporting the integration of AI into FM, but also fundamental to the successful application of AI technology in the FM field.

First, AI applications are based on data quality and reliability. High-quality, trusted data is a guarantee for the success of AI algorithms. In addition, the cultivation of talents and skills is also crucial. Having professionals who have a deep understanding of and can effectively apply artificial intelligence technology is the key to realize artificial intelligence convergence. Given its broad scope, integrating people, places and processes into the built environment, FM inherently offers numerous opportunities for technological integration. In addition, the large investment and leading position of major industry participants in FM in AI technology, as well as learning from the successful experience of other industries, undoubtedly provide strong support for the integration or application of AI in FM.

In our discussion, we will delve into these key "enablers", dissecting their key role in supporting and driving the integration of AI technologies in FM.

4.2.1 Big Data in FM

The architecture, engineering, and construction (AEC) industry generate extensive and diverse datasets, aligning with the principles of Big Data (Jiao et al., 2013). In Facility Management (FM), this data influx poses significant opportunities for AI integration and application, echoing the advocacy by the International Facility Management Association (IFMA) for data-driven FM.

Data quality emerges as crucial for informed decision-making and algorithmic responses, as highlighted by interviewed experts. The reliance on accurate data for correct decision-making was emphasized:

"...the reliability of response, the algorithm, non-disclosed algorithm. So, quality of data is essential...Today, you need to be very reliant on the correct decision taken." (C5)

Experts identified the underutilization of available building data, emphasizing the challenge of harnessing this valuable information effectively:

> "...what I see is that the technology we already have is not used yet...there's so much data available already..." (C7)

Additionally, insights emphasized the need for secure data flow and leveraging extensive data to drive actionable decisions:

> "Efficiency and decarbonization require looking at a lot of data to enable decisions and actions...vendor-driven approaches need actionable insights..." (C1)

Furthermore, AI's potential in optimizing efficiencies through intelligent data utilization was recognized:

> "...the big question is how do you use them...AI is everywhere, and we need to utilize it effectively..." (C2)

However, it's essential to acknowledge that data, while enabling, also presents challenges. The abundance of data necessitates effective management, as will be discussed in subsequent sections. This dual nature of data signifies both opportunities and challenges within FM's AI integration landscape.

4.2.2 Technological Collaboration

Within the spectrum of Facility Management (FM), several experts highlight the pivotal role of technical collaborations as a cornerstone strategy for achieving AI adoption. These collaborations serve as fundamental conduits through which FM companies leverage expertise from professional technology partners. Such partnerships facilitate the integration of existing technologies, compensating for inherent shortcomings in AI technology updates and model development within the FM domain.

Experts advocate for strategic alliances and collaborations with specialized technology firms, elucidating the pragmatic approach of FM companies towards AI adoption. The essence lies in leveraging external expertise to bridge the gap between existing capabilities and the evolving landscape of AI technologies. These collaborations are strategically aligned to bolster AI integration initiatives within FM, harnessing the specialized knowledge and technological acumen of external partners.

> "On that part, we also should be clear, we are always looking for technology partners with a specialism today, in AI we're not developing models ourselves. We are re-deploying or deploying existing technologies into our products, of course, because we don't have the capability today to build their own models, and we don't know what it's going to be interesting at any stage, probably will, and then AI will have moved on quite a lot." (C5)

> "Also we are an FM industry player, we are a FM company, we are not a technology company. So, AI will in some ways need to be supported, technically wise, to have a fitting solution." (C4)

> "…but the second part is software. We are a business partner of a US based company in software for facility management. So they have an integrated workplace management system or Facility Management Information System or all different terms for the same thing.

The symbiotic relationship built by technological corporations is considered as an important catalyst to drive the effective implementation of AI in FM companies. This partnership enables FM entities to embrace the complexity of AI development, ensuring alignment with industry-specific needs and technological advancements. Thus, this strategic coupling allows FM companies to enhance their technological capabilities while making full use of external expertise to create an environment conducive to AI integration. These collaborations represent strategic investments in knowledge exchange and skills enhancement. By collaborating with skilled technology partners, FM entities not only gain novel insights into AI applications, but also cultivate in-house expertise. This injection of knowledge empowers the FM industry in mastering the complex landscape of AI technology, thereby fostering a culture of innovation and adaptability within the industry.

4.2.3 Large Service Providers are Enabling the Trend

Major international companies are identified as key contributors to advancements in Facility Management (FM) through their significant investments in new technologies. They do it as a way to improve efficiency and solve workforce scarcity. One interviewee mentions:

> "I think we need to rely on the large service providers. For example, ISS, we probably know it as a service provider focusing much on cleaning, but also on a lot of other FM services. So they're actually building an in-house IT company just to do innovation, and to work on new technology that can support services, because we know from demography that we need to find a solution to the lack of human resources in operational services that are placed in the West European or in the European region. So they're focusing on how they can use technology services." (C7)

Sharing a similar perspective, another interviewee believes that the ability to automate tasks without human intervention is crucial. Furthermore, he envisions a transition from algorithms to artificial intelligence (AI) as the next step, with a focus on creating valuable advisory services:

> "I think the main enablers are linked again to the love for talent and about putting more efficiency in the resources and automating anything. Automation is really the other one, which is really important because you can do a lot of interventions without human intervention. I think you can do a lot of smart things but again, that's the next step. I think if you can then create more advisory coming from this all, I think, this will be the greatest advantage and then we are going to move away from algorithms to AI. So I think, for me, it's about putting your resources more in an efficient way, automation. I think it's really an important one…" (C6)

In summary, major international companies are driving development in FM by heavily investing in new technologies and focusing on automation and efficiency to combat workforce shortages, with a future shift towards AI-based advisory services.

4.2.4 Learn Good Practices from Other Sectors

The interviewee considers advancements in AI from sectors such as insurance and banking as an enabler for AI integration in FM. He suggests learning from and collaborating with these industries to implement successful AI solutions within the Facility Management sector:

> "We need to look into other sectors, for example, the insurance and banking sector, they already are very advanced with AI. For example, in their help desk applications, we should learn from the other sectors, try to get involved with them, and see how we can implement the solutions they use in the FM industry…." (C7)

Emphasizing the interconnected nature of FM with various organizational departments, he sees it as a readily adaptable domain for AI tools. The horizontal function of FM is highlighted as a crucial facilitator for the effective implementation of AI:

> "FM is connected to all these departments, it's very easy to adopt tools and AI tools… horizontal function of FM in organizations, it's a very important enabler for implementing AI" (C7)

In summary, the interviewee suggests leveraging advancements in AI from other sectors to enhance AI integration in FM, highlighting FM's horizontal function across departments as a key facilitator for effective AI implementation.

4.3 Barriers for AI Integration in FM

Our interviews revealed that there are also significant barriers to the smooth integration of FM with AI in facility management today: including legacy technology, reluctance to change, fragmented incentives, change management issues, data management issues, and skills gaps. Addressing these challenges requires targeted strategic planning and proactive measures.

4.3.1 Legacy Technology

Legacy technology poses a substantial hurdle for AI integration in Facility Management (FM), as highlighted by industry experts. Disparate and outdated systems within FM operations lack integration, hindering AI adoption. A facility management expert highlighted the absence of a unified Building Management System (BMS), expressing doubts about AI's role due to existing data capabilities and standard predictive maintenance technologies:

> "You have the building management system...no umbrella system that connects all the fields...not convinced that AI is going to play an important role...standard technology...you don't need the AI for this..." (C7)

Additionally, skepticism among FM professionals about AI's role, often perceived as robotic automation, is rooted in the reliance on human judgement for nuanced decisions in facility operations:

> "The vast majority of AI in facilities is just robotic process automation...facility professionals make a lot of judgments...completely automating that with AI is a scary thing…" (C1)

The challenge is compounded by outdated FM systems like chillers and boilers lasting up to two decades, presenting a hurdle in data normalization essential for modern AI frameworks:

> "We're dealing with legacy technology...the data that is available is really old...normalizing that data so that it can be used in an AI model is a big challenge." (C1)

In facility management, traditional technical barriers manifest themselves in doubts about different systems and the applicability of AI. A comprehensive strategy is needed: upgrade and improve facility management systems to make them more compatible with modern system requirements and able to work with AI technologies.

4.3.2 Reluctance to Change

A significant hindrance to the adoption of AI in the FM industry is the lack of awareness and reluctance to change among individuals working in this field. One interviewee notes that a significant barrier lies in the lack of awareness and understanding among people regarding what AI is and how it can contribute to FM services:

> "I think the barrier today is that people are not aware of the fact that they don't know what AI actually is. And so they do not have the knowledge of how AI can be used and how AI can contribute to FM services. I think that's a barrier." (C7)

When discussing the average age of facility management, one interviewee emphasized the need for younger personnel who are more tech-savvy to support AI integration:

> "In the United States, I don't know what it is for Europe, the average age of a class of facility worker, like electricians in their mid-50s. So getting a younger talent pool in the FM ranks that is digitally native is going to be essential to pushing that forward." (C1)

He also highlights that with a non-technology company, the adaptation to new IT solutions, including AI, is a challenge both technically and psychologically within the organization:

> "Also we are an FM industry player, an FM company, we are not a technology company. So, AI will in some sort need to be supported, technically wise, to have a fitting solution. And we have an experience with that in the company when we are starting to use new IT solutions, so not even AI solutions. But IT solutions always need to be adapted somehow. It needs to be adapted, technically, but also psychologically by the people inside the organization. And since that's often that's not that easy, because we're not this technology company, we're a facility management company." (C4)

Furthermore, one interviewee suggested the long history and size of certain FM companies pose a barrier to AI integration. Daily routines and resistance to change, particularly from long-term employees, can hinder the adoption of AI. This interviewee expresses concern about the vulnerability of established companies to the disruptions by more agile, AI-driven startups:

> "I think the fact that we have a long history is also a barrier. Because we are a big company, with 10,000 people working in Belgium, but also in the world around 50,000 people. So that means you have many routines that are fixed, you have people in the company for ages like me, and it is difficult to change them. They think well, no, we don't do that this way. So, it's probably much easier for a new company, 'Uber for cleaning', or the 'Uber for catering' to just wipe us out of business through AI. And that's where I see the real, real danger." (C3)

The interviewees highlight the lack of awareness and resistance to change as an important barrier to adopting AI, marked by many challenges including unfamiliarity with AI's potential, an aging workforce necessitating younger, digitally adept talent. Organizational adaptation to new IT solutions encounters technical and psychological hurdles, given the industry's non-technology focus. The long history and size of certain companies create vulnerability to be disrupted by more agile, AI-driven startups.

4.3.3 Split Incentives

In facility management (FM), the concept of "split incentives" for AI integration involves multifaceted challenges from different perspectives. The conflicting interests between industry and individual stakeholders form a fundamental paradox. Although the FM sector requires operational data from individual buildings, concerns about privacy and protection of individual user data significantly hinder data access. One of the interviewed experts highlighted these difficulties due to privacy issues within buildings, highlighting potential obstacles in AI implementation.

> "Because you cannot just walk into somebody else's building and start putting up sensors and getting the data to gateways… so that's different. So that's where I see a possible similar problem with AI." (C3)

At the business model level, the dichotomy between business-to-business (B2B) and business-to-consumer (B2C) models exacerbates the lag in AI adoption. Compared to B2C, FM companies operating mainly in B2B environments have a slower AI implementation rate, limiting the widespread

implementation of new applications. One expert highlighted the difference in AI application and implementation potential between B2B and B2C models.

> "When it's 'business to consumer', you have this vast, vast commercial opportunity, when it's 'business to business' is completely different, you know, you don't have that fan amount in terms of one product and install it for millions of people all at the same time." (C5)

Furthermore, dynamics within large FM companies, often acting as service providers, face the challenge of the "split incentive." This dilemma arises from misaligned goals between the client (principal) and the FM company (agent). The drive to reduce operating costs, crucial for clients, paradoxically diminishes the FM company's revenue, as expressed by an interviewee:

> "And so, when you're coming back to 'motives', and for facility management, there is a split incentive... Everyone's always trying to drive down costs, but in this turbulent Financial Times for commercial buildings with interest rates going up. They're trying to drive down the operating costs, well, that is counter that reduces the revenue of the facility management company." (C1)

Lastly, internal barriers within FM departments, including the challenge of obtaining support and understanding from higher management and other departments, contribute to the complexity. Convincing C-level executives and IT departments about the efficacy of AI integration remains a significant hurdle, requiring comprehensive organizational buy-in, as noted by an expert:

> "Then the facility manager still needs to sell that to the C level... But also, you need to convince the whole organization and probably also IT." (C2)

These multifaceted dimensions - conflicting interests, business model disparities, the split incentive dilemma, and internal departmental barriers - collectively contribute to the pervasive challenge of "Split Incentives" in AI integration within Facility Management.

4.3.4 Change Management and Staffing Model Concern

In facility management (FM), AI integration is challenged by the "change management and staffing model problem". These include aspects such as change management measures, stakeholder engagement, and potential staffing model restructuring. Implementing AI solutions requires significant change management efforts. This means that there needs to be a shift in working methods and practices within FM. Experts emphasize that change management plays a key role in successful AI integration. One expert highlighted the nature of coping with transformation through change management in the FM domain:

> "Because at the end of the day, what we're dealing with is change and call it 'change management'." (C1)

Additionally, involving stakeholders in change management is deemed essential for successful technology adoption, particularly when AI disrupts existing work patterns, as highlighted by another expert:

> "...if you want to do something, you need to involve them in change management, if you want to be successful... a different way of working and a different way of approaching services." (C6)

Concerns arise regarding employee engagement and technology acceptance, particularly in adapting to new work methodologies. Experts note the reliance on human judgement and the perception of AI potentially replacing traditional approaches, shedding light on the impact of AI on job roles:

> "...to replace that with a smarter way of working, driven by AI will now sustain a lot of interfaces to get to the human." (C3)

There's ambiguity surrounding AI's impact on job displacement, contributing to employee apprehension, as highlighted by an interviewee:

> "AI is taking away jobs. That's not true. It's true and it's not true." (C6)

In addition, the need to modify the staffing model due to the implementation of AI has triggered reluctance within large FM companies. AI technology has upended the traditional way of staffing, raising concerns for large FM companies that operate primarily as staffing providers. These companies may be concerned because the application of AI may change their traditional roles and business models in terms of staffing, with some impact on their operations:

> "...FM companies today are mostly staffing companies... They view AI privately as breaking up their staffing model." (C1)

These challenges encompassing change management, stakeholder involvement, employee adaptation to new technologies, and the impact on staffing models collectively hinder the seamless integration of AI within Facility Management.

4.3.5 Data Management and Privacy

Many interviewees highlighted a barrier related to data and privacy concerns in adopting AI in FM. Interviewees underscore the need for a robust data management strategy and data privacy:

> "For me, one of the barriers is data management. Because facility management is not used to working with this. So if you don't have a data management strategy, it is going to be really difficult. If you don't know which data you can capture in your building or building portfolio, then it's an issue and I think first, you always have to ask the same questions: why? What do you want to do with this data? And then you can ask the question about which technology do I need? And I think AI could be one of those technologies that can help. So I think data management is the initial question." (C6)

> "Other barriers may be about data, data knowledge, privacy reasons, perhaps, I think there's a huge barrier." (C4)

An interviewee highlights the intricacy of FM services compared with other services provided in public spaces, emphasizing the unique challenges associated with their on-site work:

> "Also, another important point is we do our services at the customers' site, which is a whole lot more complicated than driving an Uber because you're driving an Uber, or you're delivering meals, you're on the public roads. So, there's no problem there. But our services are performed behind the reception desk, behind the security walls of our customers, and even working with data at our customers' sites is a headache." (C3)

One interviewee elaborates on the importance of data privacy, specifically in relation to the GDPR (General Data Protection Regulation), giving an illustrative example of where data privacy issues and GDPR restrictions were encountered in Germany:

> "I'd say, you know, GDPR, in your definition of the words, data privacy is a huge deal. And where the government lands around data privacy, again, it is way ahead in the United States as this topic is important. But you can't take it too extreme there. Just to be really clear, for example, we have European customers, and one of our European customers wanted to go on our management service in Germany. And when we got there, when the team was putting it in, we were told that we couldn't connect the building, because of data privacy issues and GDPR." (C1)

One interview discusses the increased technical complexity when deploying AI for personalized services to individuals, emphasizing the need to understand personal preferences. He notes that this level of personalization may pose potential privacy concerns and could lead to limitations in the application of AI for catering to individual preferences:

> "When we're going to deploy AI around personal services to individuals to people, it's getting much more techie. Because they get into understanding how you are as a person, what your preferences are, how I can basically interact with you in the best way to get you happy or unhappy or whatever. Which is a potential breach of privacy ruling, as well. So there might be limitations there, where we are going to see limitations and the application of AI towards personal preference, for instance, could be." (C5)

Several interviewees highlight data and privacy concerns as key barriers to AI adoption. Emphasis is placed on the need for a robust data management strategy and the challenges arising without a clear understanding of what data to capture. The complexity of on-site facility management services is discussed, emphasizing the unique obstacle of managing customer data in FM environments. In

addition, there's an acknowledgment of the increased technical complexity of deploying AI for personalized services, with a recognition of potential privacy concerns and limitations.

4.3.6 Skills Gap

The skills gap is also considered a barrier for the FM industry to adopt AI. One interviewee notes that even new startups face challenges due to a lack of digital knowledge and frequent changes in personnel:

> "Even those new companies as new startups will struggle with the things we just mentioned, the lack of digital knowledge, the fact that our people are often changing very often." (C3)

Some interviewees suggest that the absence of skilled individuals hinders the ability to deliver required services, preventing the allocation of resources for research or innovation:

> "...I think it also has to do with skills, it is connected to resources that host the service providers and in-house FM department, they don't have skilled people to provide the service. So if you're not able to provide the service that you have to do today, you cannot spend resources and have no skills available for research or innovation." (C7)

> "...let's say the skill set of the current facility manager is not there yet. They don't notice the right skills yet, or they don't have the right profiles within their FM team to work with…Secondly, the barrier is definitely as I mentioned before, the lack of skilled professionals to work with artificial intelligence in operating and managing buildings. So I think that's the second. So creating awareness and having the right skills are those are for me the largest barriers now." (C2)

> "I think concerning barriers, depending on how AI would be used, so if the front line or the people on the ground are involved, that's what just explains a lot of barriers in terms of using the application of people who are not digitally savvy." (C4)

The challenges in adopting AI in FM encompass a range of issues related to the skills gap such as a shortage of digital knowledge, frequent personnel turnover, insufficient skills, and resource constraints. The common thread emphasizes the critical connection between skills and resources, underscoring the importance of having proficient individuals to effectively implement AI-based services.

STEP 1	STEP 2	STEP 3
RQ2: How is the ecosystem of Facility Management influencing AI integration from a quadruple helix perspective?	4.4 Government's Role in FM Quadruple Helix Model	4.4.1 Regulations and Standards
		4.4.2 Financial Support and Incentives
		4.4.3 Government Effort in Collaboration
		4.4.4 Government Leading Role
	4.5 Academia's Contribution to FM Quadruple Helix Model	4.5.1 Lack of Awareness and Education
		4.5.2 Academic Research Focused on AI
		4.5.3 Collaboration with the Industry
	4.6 FM Industry's Involvement in FM Quadruple Helix Model	4.6.1 Gradual Adoption
		4.6.2 Some Current Trends AI Applications
	4.7 Function of IFMA in FM Quadruple Helix Model	4.7.1 Bridging the Gap Between Academia and Industry
		4.7.2 Raising Awareness About FM & AI
		4.7.3 Lobby and Advocacy Work
	4.8 Society Engagement in FM Quadruple Helix Model	4.8.1 Public Awareness about AI in FM
		4.8.2 Public Engagement
		4.8.3 Enhanced the Workplace Experiences
	4.9 Impact of FM Quadruple Helix Model on AI Integration	4.9.1 The Regulation-Oriented AI Application/Integration in the FM Field
		4.9.2 FM as a Follower of AI Application/Integration
		4.9.3 Society Driving AI Application/Integration in FM

Table 3: Coding Tree RQ2

4.4 Government's Role in FM Quadruple Helix Model

In examining the integration of Artificial Intelligence (AI) within Facility Management (FM), the exploration delves deeper into the Quadruple Helix Model and its four interconnected pillars. The Quadruple Helix Model framework summarizes the collaborative dynamics between government, academia, industry, and society. We start with the government and explore the unique role of each pillar in driving the implementation and application of AI in FM.

4.4.1 Regulations and Standards

Many interviewees emphasized the important role of government in establishing regulations and standards to influence the market. Nevertheless, there are currently no specific laws addressing the integration of AI in Facility Management. Given that AI is still in its early stages, legislative frameworks pertaining to it are limited. The predominant regulatory concern at present revolves around data privacy, particularly in compliance with GDPR, due to AI's nature of dealing with vast amounts of data. Additionally, sustainability standards for buildings serve as a crucial catalyst propelling the market towards achieving sustainable goals and reducing CO2 emissions.

Discussing the limited legislation surrounding AI in its early stage, interviewees (C2) and (C4) pointed out:

> "I think AI is still in its, let's say… in my language, we call it children's shoes. You know, it's like, it's just starting. So, there is not a lot of legislation with regards to AI at this point. The European Commission is obviously, you know, doing a lot of things…" (C2)

> "To my knowledge, the Belgian government has not yet announced any initiative or a barrier to use AI in the workplace." (C4)

However, when companies seek to integrate AI into their organizations, the important regulatory framework to adhere to is data privacy, specifically GDPR. This is particularly crucial for Facility

Management (FM) companies, as their services often operate behind the clients' security walls, and a substantial amount of data is highly confidential. This observation is underscored by interviewees (C1) and (C4) as outlined below:

> "I'd say, you know, GDPR, in your definition of the words, data privacy is, is a huge deal. And where the government lands around data privacy, again, its way ahead of the United States on this topic is important." (C1)

> "...our people on the ground, they take a picture of something to indicate there's something broken, something needs to be fixed…. customer doesn't want this image to get out, of course. Those are things we need to keep in mind. Actually, we are in the food processing industry, where the customer is not ready to share a picture of his latest machines because they're very confidentially minded. Gathering the data and being allowed to use the data, let alone of the people and the infrastructure is a major thing. So, the GDPR framework is the key…" (C4)

Despite the significant role that the government plays in establishing regulations, interviewee (C6) remarked that the Belgian government often lags behind. The quick emergence of the AI Act by the European Commission addresses the impact of AI technologies like ChatGPT. Recognizing that FM tends to be a late adopter in technology, it is positioned as a follower compared to other industries in regulation:

> "...the government needs to play an important role because it's going to set out the regulations and how you can use or interact with data and artificial intelligence. I think one of the biggest things we saw 10 years ago was the GDPR. So it's really important to talk about data. But now we see that Europe is a little bit behind, but they are now setting out the rules, and I think everything last year about ChatGPT was really a wave. That's what's coming at us… suddenly… we don't have regulations. Now, we have to do something, we have to step up our pace and make sure that we have everything. So I think for Belgium, we really have to look at the European regulations. So I think in 2021, the first one came was the AI Act from the European Commission…as I said, we are more laggards in technology adoption. So we're not in front of the revolution. And I think if legislation is made, facility management will follow." (C6)

In addition, interviewee (C7) emphasizes the pivotal role of government, particularly the Flemish government, in driving innovation through large contracts and advanced projects. The interviewee underscores the significance of standardization, citing the implementation of the European standard for measuring buildings as a successful example. They assert that the government, given its size, can have an influence on the FM industry by implementing standards in their tender:

> "I think the government in general plays an important role in innovation because they're on the demand side of large contracts. For example, the Flemish government, in the northern

part of Belgium, their department is very advanced. And they did very innovative projects. The projects are still ongoing, and they were requesting for climate-neutral new office buildings. It's the first one in Belgium that's been built, and this is for the government. So the government plays a very important role. Also in how they use technology in the federal, federal government it's not that advanced, they also play a role. But the local authorities, they're way behind what's going on in facilities management. And maybe it has to do with the size of local authorities because you don't have a large FM department…But I think it is also related to standardization and implementing FM standards. An example is the implementation of the European standard for measuring buildings. So there has been a European standard for eight or nine years, from the moment that the federal government and the Flemish government adopted the standard and included this in the public tender documents. The market was immediately aligned on the standard. And so, by implementing standards and using definitions on facility management, the government can play an important role, because they're huge." (C7)

In summary, interviewees stress the importance of government involvement in shaping the market by regulatory framework, particularly in the context of AI and data privacy. The adoption of standards, such as climate-neutral new office buildings, plays a crucial role in driving innovation within the industry. However, there is a recognition of the dynamic nature of the landscape and a call for more nuanced regulatory frameworks specifically tailored to the FM sector.

4.4.2 Financial Support and Incentives

In the field of facilities management (FM), the key role of government was widely recognized by all respondents. However, the direct impact of government support on the FM industry does not seem to be very clear. Rather than directly providing financial support for the development of AI projects in FM, government incentives are mainly focused on innovation investment, as one respondent said: "What governments usually invest in Europe is innovation". Thus, innovation parks or laboratories may be partially subsidized by the government for such initiatives, but direct investment specifically related to the development of FM-AI projects seems relatively limited unless public services are involved.

"...what governments usually invest in Europe is innovation. So governments can invest in certain innovation campuses or innovation labs. And I think that that is definitely something that governments do. I would say the government is not financing directly… for example, innovation projects, like, an innovation campus can be subsidized partly by government fundings. That can be done, but a government will, to my knowledge, not let's say invest in a project development, unless it's for example, public services." (C2)

Only one interviewee mentioned tax incentives due to geopolitical factors. However, this perspective was not echoed by other respondents.

"I think the government's basically, as a company. I'm not talking from the point of view of the company. They are stimulating it financially, let's say subsidies on research activities

> that are being subsidized. They're going to incentivize these types of projects by taxing regulations or whatever. So it is financially… So you have these investment funds and so on...” (C5)

The reason for the limited government incentives seems to be attributable to the timing of AI technology and its nascent use in industry. Another respondent highlighted the need for FM markets to present viable, already successfully implemented concepts or products to the government for their wider adoption and promotion.

> “It could be yes, but we're just not aware of it. So, I think there are several initiatives. And if you look at a company like Imec, it's hard to imagine that they would not be involved. Yeah. I cannot imagine that they are not paying attention to that. But maybe facility management is a bit further down the line. And so the use hasn't gotten to us yet. But at the same time, don't forget that it's less than a year ago that AI burst on the scene.” (C3)

> “In Belgium, I don't see a lot of initiative yet. So I think that that's what I said before. So the FM market needs first to have some kind of, let's say, proof of concept, proof of concept or let's say product that they can teach, or they can present to the government. The government needs to adopt this and then include it in their public tenders. And I think it's not in the FM industry, we don't have yet, let's say tangible examples.” (C7)

Despite the limited visibility of direct government support and incentives in the FM sector, all interviewees expressed anticipation and hope for more conducive actions from governments in fostering a favourable environment for FM innovation and AI integration. The expectation remains that the government will take proactive initiatives to support the FM industry.

4.4.3 Government Effort in Collaboration

The experts agreed that the role of the government in promoting collaboration between different stakeholders within the FM ecosystem could be played a little more. Their collective sentiment can be summarized by phrases such as "not a lot" or "not that much". One expert put it succinctly when he said:

> “For FM at this stage, the government is not doing so much.” (C6)

Another expert echoed similar sentiments, mentioning,

> “Not a lot. It's something I don't think that the government at this point is really stimulating, that's collaboration as such.” (C2)

Although one interviewee referenced Europe's Horizon projects, highlighting collaborative endeavours across various organizations, it primarily emphasizes collaboration within industries rather than fostering the quadruple helix model involving academia, industry, society, and government. As articulated by one respondent:

> "For instance, in Europe, you have these horizon projects, you know, probably know about, in which different organizations can work together on one subject, and that's more international, in this, the more money you will get, it's a fact thing." (C5)

Together, these perspectives highlight a general notion: while collaborative efforts exist in the FM domain, they mainly revolve around specific industry initiatives or international projects such as Horizon programs, and the collaborative nature of the Quadruple Helix model across academia, industry, society, and government has not yet been initiated.

4.4.4 Government Leading Role

Despite the relatively weak role of the government in motivating policies and facilitating stakeholder cooperation, an interesting trend emerged from the interviews. That is, the government has exerted its power to guide the FM industry through its unique efforts, setting a precedent for the integration and utilization of AI in FM.

One respondent described the well-known enterprises of the Flemish government -the specialized facilities management entities. This initiative, the "Facilities Company", assumed the responsibility of managing all public buildings within the remit of the Flemish government. The enterprise takes a proactive approach to the integration of AI into the public built environment, advocating sustainable building design and a conducive working environment, making it a model for traditional companies. This highlights the government's unique initiatives in driving the integration and application of AI in the FM sector.

> "But for example, the Flemish government, they actually established a facility. They call it the facility company. And it's the team actually that manages all the buildings which are the public buildings of the Flemish government. So, they manage a building, they do all the projects, the Flemish government is in Belgium, let's say, very forward thinking when it comes to real estate, type of buildings, sustainable buildings, type of work environments where people work, etc. So, they have almost an exemplary role to standard companies, to normal companies. And that's really interesting to see." (C2)

In addition, governments play a unique role as end-users and beneficiaries of FM AI applications. Government, by virtue of its unique identity and functions, plays a key role not only as a consumer but also as an agent of technological progress, especially in promoting innovation in large-scale contracts. For example, the Flemish government is particularly notable for its progressive stance in the northern regions of Belgium, such as climate climate-neutral new office building government-led initiative unprecedented in Belgium.

> "I think the government in general plays an important role in innovation, because they're on the demand side of large contracts. And if I look to Belgium, for example, the Flemish government, so the northern part of Belgium the department is very advanced. And they did very innovative projects. Also projects still ongoing, where they were requesting for

> Climate Neutral new office building. It's the first one in Belgium that's been built and this is for the government. So the government plays a very important role." (C7)

The role of the government is not just traditional policymaking or collaboration, but to drive the FM landscape toward AI technology application as an active participant and beneficiary. This demonstration not only strengthened their confidence in the applicability of AI, but also provided practical and pragmatic support for the FM industry.

4.5 Academia's Contribution to FM Quadruple Helix Model

In discussions with industry veterans, the role of academia in the Quadruple Helix model of facility Management emerged through three different perspectives. These insights highlight significant differences in academic engagement across countries. This is the most prominent factor compared to other factors. Expert views highlight challenges, specific AI research areas, and potential prospects for collaboration between academia and industry players. This section will delve into various aspects and comprehensively analyze the impact of academia within the framework of the quadruple helix model on advancing the use of AI applications within facility management.

4.5.1 Lack of Awareness and Education

Our interviews with seven professionals from different countries revealed clear differences in FM education across countries. It is worth noting that respondents from the US and the Netherlands expressed relative satisfaction with their respective academic environments. On the contrary, the views of Belgian experts reflect different sentiments. First, they highlight the huge scope for raising awareness among young people about facility management (FM) as a career pursuit.

One interviewee underscored this perception, stating,

> "Because a lot of the young people don't know what facility management is. And it basically comes down to that. And I use that a lot in presentations that I give. If you ask 100 people what facility management is. Probably half of them have no clue. And the other 50 people will tell you 50 different definitions. So that is something that we are struggling with, to really identify what is facility management, and why should it be a career of choice." (C2)

This resonates with the prevailing challenge - creating widespread awareness.

Furthermore, the existing academic resources are notably limited, with few higher education institutions offering specialized programs. In Belgium, the dearth of institutions offering FM programs is evident. One respondent echoed the scarcity of FM-centric educational resources across Europe.

> "If we talk about bachelor and masters, we only have 2, so that's it. Let's say, countries like Romania, the Czech Republic, you don't even have any university even. So that's where the problem lies, it's the lack of awareness of the industry itself." (C2)

Additionally, the absence of dedicated research institutes in Belgium was highlighted as a contributing factor. Unlike countries such as the UK, Netherlands, Germany, and Switzerland, Belgium lacks such specialized research facilities.

> "It's in Belgium, there is not a research institute on facilities management. So you have these in the UK you have in the Netherlands, Germany, Switzerland." (C7)

Moreover, the limited availability of skilled professionals in the field was underscored by the presence of only one bachelor's program in Ghent and one master's program in Liege, where the number of graduating facility managers remains stagnant, presenting a notable deficiency in adequately trained professionals.

> "...There is a lack of skilled people in history…. There is only one bachelor program in Ghent. The amount of its three-year bachelor for facility managers and the amount of students are stagnating. It's not increasing. So, there is only one master in Liege and it's where you combine working and studying so we don't have so many graduated facility managers." (C7)

This disparity in FM awareness, coupled with the scarcity of educational resources and research facilities, signifies a critical gap in academia's contribution to the FM Quadruple Helix Model, particularly emphasizing the need for enhanced educational initiatives and resource development.

4.5.2 Academic Research Focused on AI

All respondents agreed that academic research on AI in facility management (FM) is critical. It is worth noting that experts from both the United States and the Netherlands, where the academic atmosphere of FM is strong, affirmed the role of academia in disseminating and sharing knowledge. One respondent stressed that universities must play a more active role in developing advanced understanding, knowledge and capabilities regarding AI technologies. Such proactive engagement is considered essential to guide AI development trajectories and develop skilled individuals for societal deployment:

> "Knowledge, of course, is the core. Let's say, advanced knowledge development takes and should take place. More universities, then, of course, the problem today with AI, look at AI today. What you now see is that the, let's say, the fortune tech companies like Google, ChatGPT now or whatever, are effectively doing the research and development today around AI. And they own it. And that's a problem because I think it's going to be so important. They should almost be common, commonly owned technology not owned by companies who are working on it today, who easily are rich about it. But it's there. Where I see Higher Education universities play a role is, is basically developing that advanced understanding and knowledge and capability on these types of technologies and play a role in how the technology will develop itself, on the one hand. And then providing the people who know how to deploy it for the society. But I think the universities need to carefully reassess how they're going to operate in these fields, because they must take a more permanent role than they do today. They must lead more than they do today." (C5)

Additionally, another respondent underscores the significance of research efforts in making both the government and industry cognizant of ongoing advancements:

> "I think they have a really important role to play and I think the thing about research and the thing that you're doing and all the reports that are made, I think it's really important to make the government but also the industry aware of what is happening." (C6)

Conversely, an expert from Belgium places emphasis on the need to nurture FM professionals with AI-oriented expertise through educational institutions. This underscores the pivotal influence of education on the industry:

> "We need a lot with universities and professors that are working in FM or with FM or in real estate and engineering. And there is a lot out there. AI is definitely a topic that is very relevant for them to do research on, to publish research, to speak on." (C2)

However, the existing academic resources are limited, with only a few institutions offering degrees in facility management, thereby impeding extensive research:

> "Yeah, we have 2, not universities, but colleges: one is in Flanders in Gent and one in Wallonia in Liege that have bachelor's degrees and graduate degrees in facility management. I haven't seen yet that they're working on things (AI), but that doesn't mean it doesn't exist." (C4)

Moreover, there is a recognized need for more educational institutions to engender a greater number of FM professionals well-versed in AI technologies:

> "We need a lot more. A lot more. We are not a technology company by heart, we are very operationally driven. I assess the group has invested heavily in technological knowledge and expertise enrolling a lot of experts. Over the past year, I think we hired something like 100 to 150 IT people and engineers. So, they're probably more involved with AI things than we know of. But we still need more if you're to benefit from the evolution in AI." (C3)

The varying approaches to AI-focused academic research across different countries underline the necessity for comprehensive and specialized educational programs to equip FM professionals with AI skills.

4.5.3 Collaboration with the Industry

An essential aspect of academia's role in the Facility Management (FM) Quadruple Helix Model lies in its collaboration with industry, where theory meets practical application. As one expert aptly stated,

> "I think that's important to work together with the industry and to see what it is because it is not a science. So facility management is another site. It's professional. So it's what you

do in research in facility management. It needs to be applicable. So you always need to, you need to prove it actually, you always need to work on a business case." (C7)

Divergent levels of academia's collaboration with the industry are noticeable across different FM academic developments in various countries. The United States and the Netherlands demonstrate relatively ideal collaborative practices:

> "...via interacting a lot with the universities in FM, which has an AI section on its own. So, we have a lot of students down here who do internships and they graduate here with us on different topics, you know, that's nice, and then some of them stay alone." (C5)

In contrast, Belgium's academic-industry collaboration exhibits irregularities, with the FM industry predominantly nurturing academia:

> "Yes and no. So we work together with Breda University, Breda University of Applied Science. So in the last few years, each time a student did an internship with us, I think it's also always interesting to see what they bring from their academic background to the labor market. So I think it's really important to see, but also for them to learn, because there is always a big difference between the theoretical approach and practical approach. So I think it's really important." (C6)

> "We sometimes go there to give a guest lecture or to go to initiatives, just to see if we can recruit some of the young graduates. But it's not a real academic corporation." (C5)

Additionally, a more pessimistic view highlights the rarity of collaboration between the AI-related FM industry and academia. Often, valuable information generated in academia remains within academic realms and doesn't permeate industry practices:

> "But unfortunately, I think the fate of researchers at universities is that what they do usually stays within the academic atmosphere and rarely goes outside, although I really think it's important, I think. And to be honest, that's not only with regards to AI…But there is no connection, an obvious connection or a natural connection between the researchers/universities and the actual practitioners, I would say." (C2)

Academic and industry collaboration between different countries highlights the need for a more structured reciprocal relationship between academia and the FM industry to ensure a seamless transfer of theoretical knowledge to practical implementation.

4.6 FM Industry's Involvement in FM Quadruple Helix Model

The FM industry is often perceived as lagging in the adoption of AI practices, especially when compared to other sectors. This delay can be attributed to various factors, predominantly the challenges associated with data management, as well as a general shortfall in industry-specific AI knowledge and skills. Despite these hurdles, numerous prominent international companies within the FM sector are making significant financial investments and spearheading the drive towards AI

integration. These leading players anticipate that AI will not only enhance operational efficiencies but also provide a solution to the industry's resource shortage issues.

4.6.1 Gradual Adoption

The interviewees' statements provide insights into the slow and cautious integration of AI in the facility management (FM) service industry, highlighting various challenges and perspectives.

Interviewees (C1) stated that there's a discrepancy between discussing AI and actually implementing it, with actual progress being slow:

> "Slow, that they're very fast to talk about it. But they're very slow to walk about it." (C1)

Emphasizing on the slow implementation of AI in the industry, interviewee (C3) noted that while many players discuss AI in their offerings, actual adoption is limited mainly to the top-tier companies. This slow pace is attributed to the lack of resources among smaller players, who constitute the majority of the industry:

> "I would say slowly. Again, it depends on how you're using it. And I think that the entire industry you have, let's say if you have 100 players in the industry, 90 of them are rather small, they don't have the resources to make a significant investment in AI. So, you're talking about the top 10… I wouldn't be surprised if a lot of players are already talking about it in their offers towards customers. But the practical implementation would be rather slow." (C3)

Interviewees (C6) and (C7) both elaborate on the fact that large international service providers are investing in AI for backend solutions, especially for business intelligence, due to their substantial resources and data from various countries:

> "I think a lot of international service providers are investing a lot of money in this, but then more in their back-end solutions. This is what I mean about their business intelligence. So they invest a lot of money in if they are a global company. I can imagine you have a lot of data from each country. You want to see productivity, efficiency, all those kinds of things. Then you have a lot of data and then you need to apply AI to make those reports and then, of course, make predictions. And I think this is now how it will be incorporated into facility management. But again, this is for big service providers, for example, like ISS or Sodexo. So all those kinds of companies because they have the 'must', they have a lot of revenues so they need to invest and need to evolve to adopt AI." (C6)

> "I see some examples with the large service providers. But again, many of them are focused today on finding resources, they don't have time to spend on innovation, or new technology. But there's an example that I think of, CBRE. So let's say the international players are investing in innovation because they really see the added value. And they also see that there

> they can find a solution with technology including AI, for the lack of resources. And this is what these large service providers are doing." (C7)

Interviewees (C4) and (C6) highlight the industry's cautious approach to AI, a factor contributing to the slow pace of its adoption:

> "We've experienced this with IT in the past. When you start an offer, you're talking about IoT, and everything is fun, and everything is very exciting. But two years later, you sign the offer. And they just see that it's not adding that much value relative to the high cost. And that's what shows in the industry." (C4)

> "The FM service industry is in the laggards so really slow, and why? It's always the same. Yeah, let's see what it will bring us and first I want to see a lot of use cases. And that's how it goes. But yeah, you know, in your daily life, it's already applied everywhere. If you open Netflix, it's going to say: Hey, these are the series and films you need to see because it is just taking your data and saying this is what you like, so this is what you need to see…" (C6)

In addition, many interviews mentioned many challenges that companies are facing in adopting AI. Interviewee (C6) stated that data management is a new and challenging domain for those in facility management, traditionally an operational field:

> "...it always starts with data management. And I think we have a lot of challenges with that. Because in facility management, data management is a new domain for the people involved in that area, because it used to be really operational. And now suddenly, a lot of data is generated in the buildings and how are we going to work with it?" (C6)

According to interviewee (C1), successful AI integration requires changing processes and training people, not just technology adoption:

> "Lack of understanding! You've heard 1000 times, it requires people, processes and technology. And AI is the technology. If you don't change your processes around AI, and then don't train your people, but at least we start with raising their awareness, awareness and getting them to acknowledge that there's a better way, then the change doesn't happen." (C1)

AI use in operations is not widespread and requires competence in both usage and understanding, which is currently lacking:

> "Slowly and carefully. Very, very, no, I think the whole, in terms of a good go to the operations fields, operating they are not using it. Well, some are here and some are there, it's not that broad. It's not a broad adoption program because they need the competence to use it and to understand what you're doing. And that's just not that today." (C5)

Besides emphasizing the complexity of AI integration, interviewee (C2) also noted that Facility managers not only need to understand and see the benefit of AI but also must convince their organization's higher levels, including IT departments:

> "It's a slow integration. I really see that and it's complex, it's really complex, I understand using AI in your operations or knowing or understanding how to use AI in your operations is really a complex matter. And not only that, but the facility manager might also see the benefit. Then the facility manager still needs to sell that to the C level, to the CEO or to the finance department or to whatever. So it's not only you as a Facility Manager, they need to understand or need to be convinced about it. But also, you need to convince the whole organization and probably also IT." (C2)

In summary, the adoption of AI in the facility management service industry is marked by a slow and cautious approach, reflecting a disparity between enthusiasm for potential benefits and practical implementation. While large international service providers are investing in AI for backend operations and business intelligence, recognizing its value for data management and efficiency, the majority of industry players, especially smaller ones, lack the resources for significant AI investment. This slow progress is further compounded by challenges in changing operational processes, training personnel, and convincing organizational leadership of AI's benefits. The industry's cautious attitude mirrors past experiences with IT and IoT, where initial excitement did not always translate into long-term value relative to costs.

4.6.2 Some Current Trends AI Applications

All interviewees agreed on the fact that FM is still in the early stage of AI, mainly researching and developing AI applications. However, they noted that certain applications are gaining significant interest due to their potential to address key challenges such as labor shortages and enhancing operational efficiency.

Interviewee (C5) stated that the most popular AI application in their field is expert assistance, which could rapidly address labor shortages:

> "I think most popular in our field…I think the whole setup of assistance, so let's say, field-specific assistance, like, I am a specialist on a track, I have an AI that will explain to me if I see this and that, what might be the problem? If I have, that kind of thing might be one of the first implementations, we will see because it's basically about knowledge management… The value of that is that it will help a certain age, a situation as we're confronted with today, which is lack of labor. There are fewer and fewer people in this field specialists in certain areas, you have less and less people, so in your daily job as an engineer, having an assistant that will tell you about some specialized equipment that you still need to maintain, but you don't know much about it, then you can just ask your colleague, what's happening here? And what do you think? What's your analysis? Can you help me with understanding what I'm looking at, that's kind of thing… That's something I think will happen. And it can happen fairly fast, we can do that." (C5)

He also shared that his organization is looking into AI applications for assessing footprints and improving footprint and energy consumption of buildings:

> "We're working with Schneider AI hub... The Schneider AI hub is an organization that works on AI, based on building and digital energy application, so Microgrid, Switching that kind of thing. So, we're looking with them at assessing footprints and improving the footprint and energy consumption of buildings. We have been buying into generic AI technologies from Microsoft, so copilot." (C5)

Interviewee (C4) highlights that in their sales department, GPT chatbots could significantly streamline information retrieval, replacing time-consuming searches through files or inquiries. In operations, these tools could enhance efficiency and clarity in tasks:

> "For us, I think in the sales department, I would say some kind of GPT chatbots, where in sales can just find every information, they need to find via the chatbots instantly. Because what happens now in practice, either we need to look into 1000s of files and you limit yourself to the first five, you don't look much further. Or we need to ask around, and it takes days before you find the right person and then the right information. While most of the time, let's say 90% of the questions that are asked could be answered via the chatbot. And in operations, tools, either for rostering for translation or to explain better what's expected in the work for people on the ground, just to make operations more efficient, and to close these gaps… It can make us organized more efficiently by a factor of 10 and thus saving a lot of resources." (C4)

Interview (C3) expects that AI applications can help them to provide better service in food service:

> "I also think about possible applications in good services. I can imagine that the AI that looking at all the data that we gather about meals being consumed, about the impact of those meals, how they're being consumed them or what patterns that could be used to generate much better solutions to individual customer needs, or to transfer best practices from one to another site." (C3)

Besides the assistant application, interview (C7) also mentions about the robot application:

> "I mentioned that the first is the help desk… let's say the system gives you an answer instead of having a help desk officer, who should reply to your request. It's the system that is based on data available and on the additional AI layer. For example, if the light bulb is not working, there are a lot of solutions before you need to replace the right light bulb. And these are components that you can include in your system. And I think the second it's about the robots and the cleaning and the robots with the AI also doing surveys in large buildings, like security surveys." (C7)

In addition, he believes that while AI has more potential to enhance the 'soft' aspects of facilities management, the challenge in 'hard' facilities management lies in effectively utilizing existing technologies and data, with skepticism about AI's necessity in areas like predictive maintenance where standard algorithms may suffice:

> "Adopting AI in FM would be more connected to the soft part of facilities management. I think there is more added value for the facility manager…I see that the technology we already have is not used yet… In the hard part of Facilities Management, the challenge is to use the existing bill or the existing technology today and to make it really add value with the existing systems towards organization… There is no umbrella system that actually connects all the fields, all this data and I am not convinced that AI is going to play an important role in this because I think it's the data we have. And then of course, if you talk about predictive maintenance, then you're trying to predict what's going to happen based on a couple of parameters. But you don't need AI for this. It's standard technology, its parameters, interpretation of parameters, and you have an algorithm done and you can change so you don't need the AI for this." (C7)

In summary, AI is expected to provide many solutions, including employee support, technical assistance, and energy management, with greater potential identified in the "soft" aspects. Nevertheless, the slow pace of adoption indicates that FM is still in the initial phases of researching and implementing AI applications.

4.7 Function of IFMA in FM Quadruple Helix Model

IFMA serves as a pivotal anchor in the FM ecosystem, playing a crucial role in shaping the future of this industry. It bridges the gap between academia and the FM industry, a vital step towards fostering a more integrated and informed professional landscape. IFMA's commitment extends to raising awareness about the significance of Facility Management and the transformative impact of Artificial Intelligence (AI) within this sector. Additionally, its influential position enables it to engage in effective lobbying and advocacy work with the government on policy and regulation. This multifaceted approach underlines IFMA's integral role in steering the direction of the FM industry.

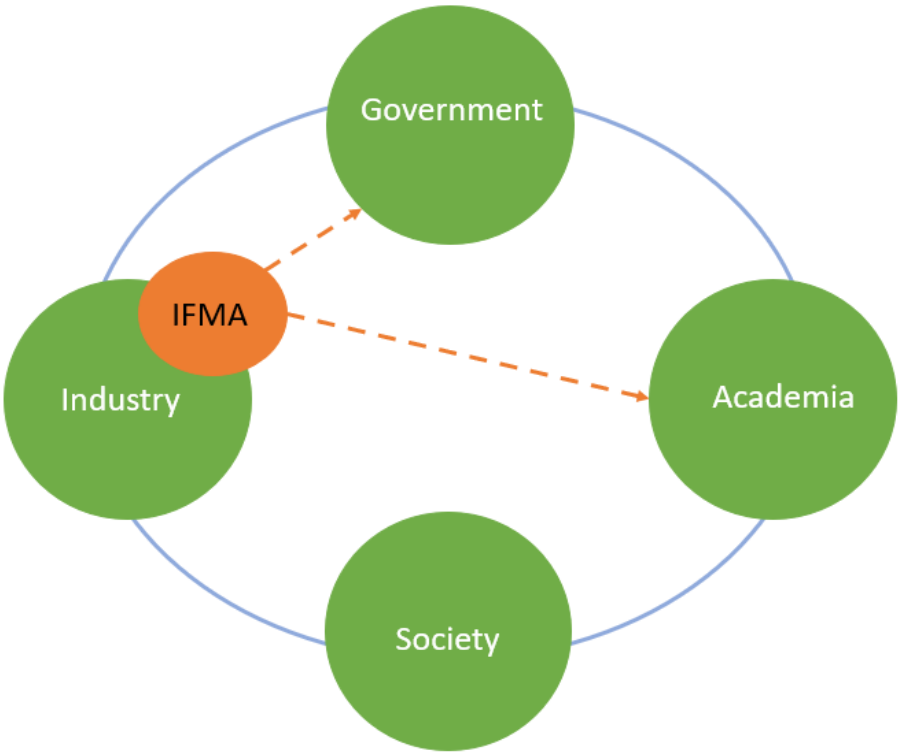

Figure 4: Quadruple Helix Model for FM industry

4.7.1 Bridging the Gap Between Academia and Industry

In the realm of facility management, there's a notable challenge in effectively translating academic research into practical industry applications, which hinders the flow of innovative ideas from scholars to practitioners. Addressing this issue, organizations like IFMA play a pivotal role in fostering collaboration between academia and industry, striving to make scholarly research more relevant and accessible to those in the field.

Interviewee (C2) shares her concern about the existing gap between academia and industry in FM. This gap is seen as a significant issue because valuable research rarely influences industry practices directly:

> "What I always feel is that the gap between academia, researchers, and the industry is enormous. It's really big. So, what they are doing rarely gets to the actual users or the facility management industry. And that's why, for example, IFMA, there are other associations as well, we try to work together with researchers and try to develop research to bring that to our members. But unfortunately, I think the fate of researchers at universities is that what they do usually stays within the academic atmosphere and rarely goes outside, although I really think it's important." (C2)

She also noted that the complexity and lengthiness of research reports, in contrast to more straightforward industry reports, is a key factor hindering their accessibility to companies. This contributes to the weak connection between research and industry:

> "It's basically a very simple thing. When a researcher writes a report, usually, and I'm not going to generalize, but in a lot of cases, it's a 300-page report which is really long, and extensive, and nobody will read it, nobody from the business will have the time or take the time to read such a report. So I always challenge researchers that I work with, to do that research, because you do need to have that report, but translate it into, I'm not gonna say dummy proof language, but make it interesting enough for people who could actually benefit from that content. And that is a huge challenge." (C2)

> "Let me give you an example. A large FM company like ISS or Planon, you know, the type of company that you have. These guys are not reading research that comes from the universities, usually do their own research in terms of surveys because they're commercial, obviously. They're a commercial company, but they do their own research. And they organize surveys among their clients and all of that, and then they develop a report and it looks fantastic. And it's really easy to read. So for me, it's also the link, really. But there is no connection, an obvious connection, or a natural connection between the researchers/universities and the actual practitioners, I would say. So that link just doesn't exist." (C2)

IFMA is working to enhance the accessibility and relevance of academic research for industry professionals by urging researchers to convey their findings in brief and easily understandable formats:

> "And that's why I'm saying that's a role that we have, IFMA, for example, try to take where we've sometimes when we do conferences, where we invite researchers to present the findings of their research, but they cannot do it in a 300-page report. They need to do it, for example, in 20 slides, and in each slide, they only can use I don't know 20 words. And it seems really funny, but it is the only way you can bring your outcome or output as a researcher's results to the industry. It's so important because they're great researchers out there." (C2)

Besides that, another interviewee (C7) highlighted that IFMA has their own research center to provide benchmarks and best practices to the industry:

> "IFMA has their own research department. Of course, they play an important role, spreading the word and working together, and I think that's important to work together with the industry and to see what it is because it is not a science. So facility management is another site. It's professional. So it's what you do in research in facility management. It needs to be applicable." (C7)

> "That's why IFMA is investing in research, so that we can also go to clients and say okay, this is where we did a lot of benchmarks, and these are the best practices, and this is what we do as a result of a research project." (C7)

Last but not least, IFMA plays a crucial role in professional training aspects of FM, addressing the increasing need for skilled professionals through dedicated training:

> "And so IFMA plays an important role in the training of new facility managers, so a lot of companies suffer from training, from skilled people and I think it's becoming worse because the challenges are huge." (C7)

In summary, the gap between academic research and practical application in the facility management industry is significant, with large FM companies often conducting their own user-friendly, commercial research instead of utilizing complex academic studies. The International Facility Management Association (IFMA) is actively working to bridge this divide by collaborating with researchers to make academic findings more accessible and applicable to industry professionals, for example, by condensing research into concise presentations. Furthermore, IFMA plays a crucial role in training new facility managers and investing in research to establish benchmarks and best practices, addressing the industry's growing challenges and the need for skilled professionals.

4.7.2 Raising Awareness About FM & AI

Facility Management (FM) confronts a substantial challenge in establishing its significance and role, as many individuals lack awareness about the field or do not consider it as a career option. In response, IFMA is dedicated to enhancing awareness of FM and AI to foster the development of this industry.

An interviewee (C2) highlighted IFMA's effort to increase public awareness about Facility Management as a viable career option:

> "Because a lot of the young people don't know what facility management is. If you ask 100 people what its facility management is, probably half of them have no clue. And the other 50 people will tell you 50 different definitions. So that is something that we are struggling with, to really identify what is facility management, and why should it be a career of choice…. Because you know, young generations nowadays want to have an impact, impact on society, impact on the environment, etc. And I think facility management as an industry can offer that. If you work within the facility industry, you really can have an impact on people's lives on well-being and sustainability on, you know, a lot of aspects." (C2)

She also elaborates on how IFMA provides trainings to many construction companies around the world:

> "What we see in the Middle East is that a lot of construction companies are actually setting up facility management companies, because they have no other option, and to train their staff with IFMA, for example. Because they need to have skilled professionals. And that's what we see going on nowadays. And the advantage of our credential programs is internationally recognized. Also, they're very popular." (C2)

Interviewee (C7) highlights the IFMA's initiative to attract young talents to FM through the Young IFMA program:

> "This is also the work I tried to do with IFMA also in Belgium. We need to promote the profession and that we need to and that's also why we have the Young IFMA program, also that we need to present diversity. We need to present the challenges in the FM industry, that young people are interested in this profession and say okay, this is something that I want to do in the future." (C7)

In addition, interviewees (C2) and (C5) emphasize the association role of IFMA to communicate, advocate, and keep the industry updated with new technologies and trends like AI:

> "And I think for me, as a representative, you know, we as an association represent the industry, I think there's a big role for us to play in, at least communicate, this is what AI can do for your organization; this is what AI is. So creating that framework for the industry; encourage that; show what it can benefit or how it can benefit. And all of that it's something that we as industry representatives, I think should be doing. It's not the case yet, I think it's doing a fairly good job at this point already. But other associations are not, for sure not." (C2)

> "I have myself, I have a session in April, IFMA in Rotterdam, IFMA Europe world's workplace where we're going to talk about what is called inconvenient conversations on digitization and AI, where we are actually discussing that topic from any number of points." (C5)

> "So the international Facility Management Association, we try to share this with our community of something happening or there are new things that we share of course with the community, but also, yeah, a lot of things are happening." (C5)

The International Facility Management Association (IFMA) is actively addressing the challenge of raising awareness and understanding of Facility Management (FM) as a significant and impactful career choice, particularly among young people who are often unaware of what FM entails. Through initiatives like the Young IFMA program and training for professionals in the industry, along with emphasizing the potential of AI and new technologies in FM, IFMA is fostering the development of this field globally.

4.7.3 Lobby and Advocacy Work

IFMA plays a pivotal role in bridging the gap between government, academia, and the industry when the government's engagement in FM is limited. The interviewee (C7) highlights the IFMA's role in educating the government about innovation:

> "This is also the role of FM Associations. you need to educate the government because government agencies don't have the drive to look for innovation. So from the market, you need to educate the people in government, then they define it in their public tender documents and then the market will adopt the same on the European level." (C7)

Interviewee (C2) noted a shortfall in governmental efforts, emphasizing IFMA's role in creating connections and lobbying:

> "I think, for example, a role that we, as an industry association, are taking up more than the government. We try to make sure that we connect people from the academia and research part with FM companies, you know, we try to have an impact on policymakers as well when it comes to our industry. We tried to connect the dots, but the government itself, unfortunately, and specifically on artificial intelligence, is not doing a lot of effort to connect the three." (C2)

> "We, as an association, do lobby work, advocacy work. So that's where we get closest to the government and then maybe give the opportunity to academics to present their research at conferences where practitioners are also present. We try to foster that communication but it's not an established or well-established connection, so that would be my Disneyland's dream." (C2)

In summary, IFMA plays a crucial role in filling gaps in governmental engagement in facility management, particularly in areas of innovation and artificial intelligence. The association educates government agencies, connects academia with industry, and impacts policymaking, striving to create integrated networks.

4.8 Society Engagement in FM Quadruple Helix Model

The Quadruple Helix model, as an extension of the triple Helix model, clearly includes society as an important pillar. In the facility management (FM) context, the role of the individual "end-user" becomes crucial due to the intricate relationship between the FM industry and its demand organizations. Moreover, since the integration of AI technologies requires a knowledge society and a knowledge democracy, society becomes an important spiral with significant responsibilities. Through the interviews, we distilled three key observations about the status quo of "social" involvement in the FM quadruple helix model.

4.8.1 Public Awareness about AI in FM

The interviewed experts believe that public awareness of the role of AI in facility management (FM) is critical. This reflects their emphasis on the critical role of society in the quadruple Helix model. However, the concerns they expressed also highlighted concerns about the model of social participation. These professionals advocate for informed social awareness about the use of AI in FM. First, they stress the need for a rational assessment of AI's potential benefits to prevent the halo effect, where AI cannot accurately generate results beyond its capabilities, and therefore warn against overestimating AI's current capabilities. As one expert stressed, it's too early to talk about immediate expectations for AI capabilities, similar to Chat-GPT for instant building diagnostics. One expert elaborated that the current limitations of AI include data requirements and the inability to perform nuanced tasks or provide comprehensive solutions for construction management.

> "So human nature is that they want to fast forward: "I want Chat-GPT for my building. Hello, Chat GPT tell me what's wrong with my building." That is a long, long way off. Because not only does that require a lot of data, but Chat-GPT is just using that category, AI is not going to then go fix, say oh yeah, but you also need to go turn off the lights and rooms 123 and four and change this setpoint and we need to get the air exchange rates up to the CPM, whatever. Ain't gonna do that. And it doesn't have the ability to be right enough for the time. I think you all probably heard the "halo effect" with AI, where it hallucinates." (C1)

In addition, the experts highlighted the need to foster awareness of data security on a societal scale. One expert pointed to the tortuous evolution of social media as an example of a cautionary tale. They advocate the development of a new, secure business model in the integration process of AI with FM, aiming to avoid the pitfalls previously encountered in social media. Experts point to social media platforms as a dangerous example of giving away data in exchange for free services. They call for a reconsideration of business models adopted in AI integration. They propose that AI in FM requires a paid service model, which aims to mitigate potential risks associated with data abuse and privacy breaches.

> "Like they did with social media, they just surrender data for free service. That's very dangerous. And they don't think too much about it, they just say an immediate, immediate advantage to themselves. Oh, yeah, happy, happy. And so I'm very explicit about AI needs a different business model than social media had to get. It needs to be paid for service, otherwise, it's going astray." (C5)

4.8.2 Public Engagement

Experts unanimously underscore the transitional journey from awareness to engagement within the Facility Management (FM) context, emphasizing the significance of involving building occupants or users in the development and application of AI solutions.

> "But that's a long way from building occupants or users actually being engaged in the process of creating AI solutions…A chatbot in the interest of a business or building could say, Okay,

> I know you, Mr. X. And your colleagues are up on the third floor. That will be fantastic. But at that point, you have people engaging with AI, voluntarily. But they're not there yet…So, I can imagine it will take a delicate process for us to introduce AI to the end user." (C4)

However, achieving this engagement presents challenges, particularly considering the paramount focus of FM on human-centric approaches. The process of engagement might face delays or complications due to constraints related to data compliance and privacy regulations.

> "I think FM needs to engage them because everything we do for facility management is the biggest change that happens, we do it for the people. 10 years ago, it was all about the building. And now it's about the people; it's about being productive; it's about employee retention… But I think the biggest question over there is GDPR." (C6)

One expert highlighted ongoing effort to initiate dialogue with the public, aiming to address potential issues and benefits associated with future engagement strategies. This proactive approach focuses on fostering information dissemination as a cornerstone for the realization of subsequent engagement endeavours. Encouraging dialogue about the application, risks, benefits, and associated business models of AI integration in FM sets the stage for informed engagement practices.

> "We are basically opening the debate on how we're going to apply it, the do's and don'ts, the risks, and the benefits and that kind of thing. Just profile the technology and make sure that people are aware of what you're stepping into and talk about the business models of their application." (C5)

4.8.3 Enhanced the Workplace Experiences

In addition to the preceding insights, specific experts underscored workplace experiences as the prime catalyst for society engagement within the Facility Management Quadruple Helix Model. They emphasized the pivotal role of experiences in today's professional settings. With companies striving to attract and retain talent, optimizing employee experiences within the work environment becomes imperative, and such experiences are inherently founded on robust engagement practices.

The optimization of workplace experiences is seen as a linchpin in talent retention and attraction strategies. Experts emphasize the need to engage the workforce, teams, and employees in defining and implementing initiatives such as help desks as a means to enhance workplace experiences. This approach intertwines engagement initiatives with tangible aspects of the work environment, creating a more cohesive and immersive experience for employees.

> "I think the first one could be the help desk where you're involved or engage your workforce and the employees and the teams in implementing and defining this…" (C7)

Furthermore, experts highlight the role of AI in augmenting workplace experiences. They underscore how contemporary workplaces place immense value on creating positive experiences for employees. This extends beyond the physical workspace and amenities, encompassing personalized environments and cultural elements that contribute to an attractive workplace. The shift toward

focusing on experiences aligns with the endeavour to differentiate companies in the competitive talent landscape. As organizations increasingly seek skilled professionals, creating an appealing and unique work environment becomes imperative for talent acquisition and retention strategies.

> "But I am a true believer that AI can enhance that experience. Yes. For me, you know, that's one of the magic words nowadays. It sounds ridiculous, but it's all about "experience". Everybody wants to have a good experience. Why do you come to the office? To have a good experience, you know, to work in the best circumstances to eat nice food or have a great coffee or whatever. Or maybe personalised the environment that you work in or whatever it is. It's all about creating experience and again, that's also linked to, for me, attracting and retaining people to a company. You need to nowadays, as companies are really looking for professionals, as a company, you need to make a difference. And you need to make sure that you create an environment that is attractive for people to come to and to work for. Not only from a physical point of view but from a cultural point of view as well… I definitely see that." (C2)

4.9 Impact of FM Quadruple Helix Model on AI Integration

In examining the impact of the quadruple Helix model in facility management (FM) on artificial intelligence (AI) integration, our interviews revealed three different models: the regulation-oriented model, the FM as a follower model, and the society-driving model. Each of these models provides its own unique perspective and describes the impact and dynamics of artificial intelligence in the field of FM. Each model highlights the key factors that influence AI integration, providing insights into the interplay between academia, industry, governance and society in adopting and leveraging AI in FM practices.

4.9.1 The Regulation-Oriented AI Application/Integration in the FM Field

One interviewee, C6, highlighted the need for clearer regulation. This reflects the pursuit of a structured framework. On the basis of government regulation, he suggested that the FM field should focus on integrated reporting and disseminating use cases to clarify the role of AI in terms of practical application to bridge the understanding gap between the different pillars. At the same time, it calls for tangible support for sustainability and GDPR compliance at the societal level. As the technological landscape continues to evolve, academics shoulder the burden of developing skills and sharing knowledge. Under such a quadruple helix configuration, facility management service providers actively play their role in adapting services, ultimately accelerating the fact and application of AI.

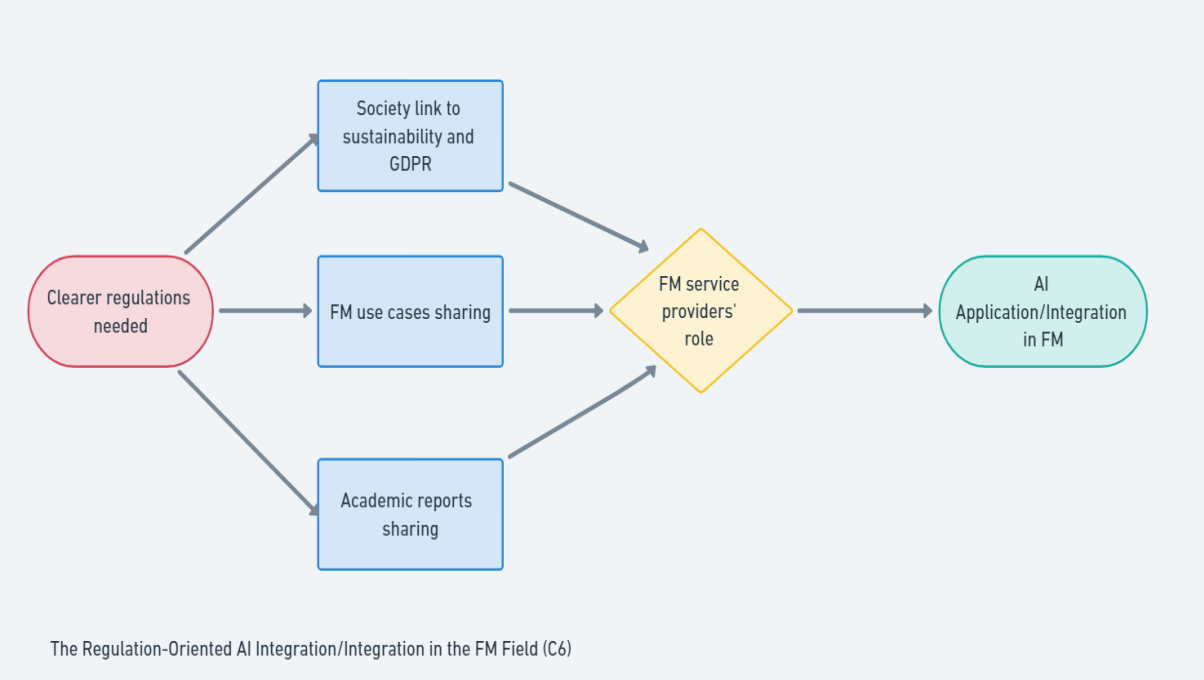

Figure 5: The Regulation-Oriented AI Application/Integration in the FM Field

4.9.2 FM as A Follower of AI Application/Integration

The Business-Driven Model underscores the decisive impact of commercial factors on AI integration. Respondents (C2) (C5) (C7) emphasised the role of market demands, competitive pressures, and technological innovations in driving AI integration in FM. Enterprises might swiftly adapt in response to market changes or competitive moves to better integrate AI technology.

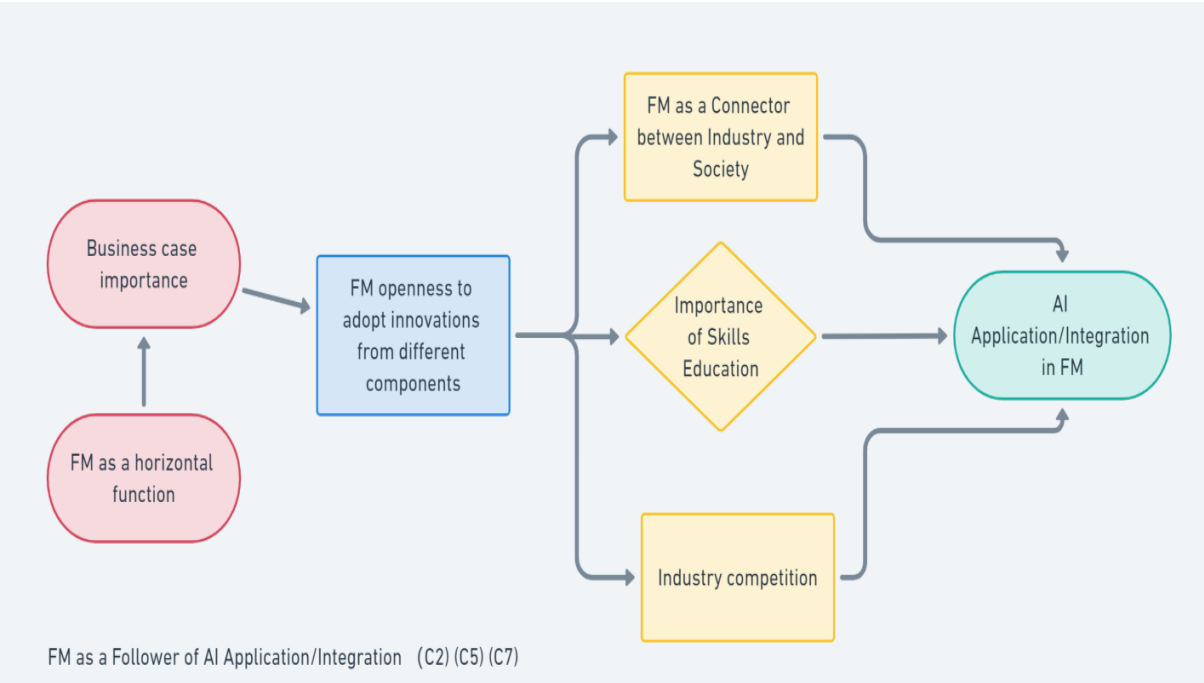

Figure 6: FM as a Follower of AI Application/Integration

4.9.3 Society Driving AI Application/Integration in FM

The model of C1 emphasizes the practical significance of social impetus, especially measures such as "decarbonization," and emphasizes the reliance on social pressure to influence industry innovation and the government's introduction of relevant laws and regulations. At the same time, he called for the key role of academic research in demonstrating the potential of AI, not only emphasizing the ability of AI, but also considering the feasibility. In addition, the government's cautious approach to AI integration regulation also needs to be taken into account.

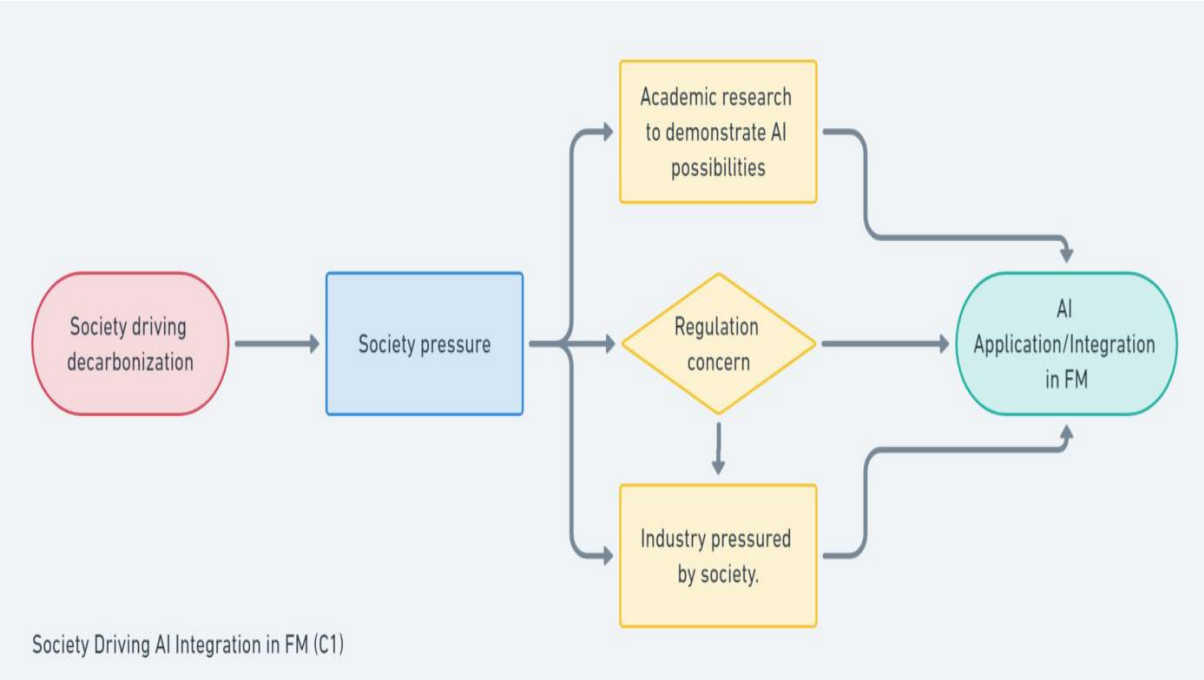

Figure 7: Society Driving AI Integration in FM

STEP 1	STEP 2	STEP 3
RQ3: How to strengthen ecosystem linkages to foster AI application/integration in FM?	4.10 Expert Recommendations	4.10.1 Skill Development
		4.10.2 Foster Information Sharing
		4.10.3 Industry Regulatory Framework
		4.10.4 Government Supports
		4.10.5 Good AI Applications

Table 4: Coding Tree RQ3

4.10 Expert Recommendations

This section of the study is dedicated to proposing strategic measures aimed at strengthening the connections among diverse entities within the ecosystem. This effort is crucial for effectively fostering the integration of AI in the domain of FM. Central to these recommendations are two key areas: first, the development of specialized skills and competencies relevant to AI within the industry, and second, the cultivation of robust channels for information sharing and knowledge dissemination among the stakeholders.

4.10.1 Skill Development

There are five out of seven interviewees mentioning skill development as the first solution to foster AI integration in FM. They highlight that ongoing education is essential for innovations in the FM industry:

> "I think skill development is the first one I just explained. If the people don't know what it is, and how it works, and you can't train them, then it will be really, really difficult." (C6)

> "For me, skill development as I said, I think that's one of the biggest things, FM's need to evolve. They have no idea how to integrate AI into their operations, daily operations. So I think making sure that they understand what AI can do for them, and for the organization that they represent." (C2)

Skill development is emphasized as a fundamental aspect, particularly in the context of AI integration into daily operations. The lack of understanding about AI among FM workers is noted as a significant hurdle, underlining the need for training to help them comprehend AI's potential benefits for their operations and organizations.

4.10.2 Foster Information Sharing

Six out of seven interviewees put fostering information as their second ranking priority in order to strengthening the linkages between 4 components of Quadruple Helix model:

> "Second place I would say foster information sharing. Because, again, you see the four ecosystem components, which will increase the use of AI in the market as a whole. And I think also in information sharing, if you have a lot of information, AI could really prove its value. And this would really increase the adoption..." (C4)

> "I think the second one is fostering information sharing because today people don't know what it is." (C7)

> "I think they foster innovation in information sharing, as you said, because again, I think associations can play a big role in this. But again, it's bringing the different stakeholders together. It's not just one thing for business. It's also the government. It's also an academic, academic approach." (C6)

Fostering information sharing is identified as a key factor in increasing AI adoption, with a focus on the collaborative role of different stakeholders. This approach is expected to enhance the understanding and value of AI across various sectors, thereby driving its wider use and innovation in the market.

4.10.3 Industry Regulatory Framework

The regulatory framework is viewed as a driving force for innovation, playing a crucial role in fostering a robust ecosystem and facilitating the integration of AI:

> "I think the first place is the industry regulatory framework. Because as I understand it, it will kickstart or push the AI innovations in the market in the industry as a whole. Therefore, having an effect on business. You don't want to get left behind. So this was for more innovation and more strengthening of the ecosystem." (C4)

> "And then 'industry regulatory framework', as you say. The industry itself has a responsibility there." (C2)

Thus, the regulatory framework not only initiates and propels AI advancements across industries but also underscores the industry's own responsibility in shaping a dynamic and innovative future.

4.10.4 Government Supports

One interviewee highlights the importance of government support in stimulating AI integration, citing the Czech Republic as an example:

> "Then let me go first to "government support". What I've seen, for example, with the example that I gave in the Czech Republic, I think that's amazing. If the government can really stimulate the integration of AI in some way or form without it becoming too directive and too narrow." (C2)

4.10.5 Good AI Applications

Some interviewees suggested good applications can help to foster AI integration in the FM industry:

> "So if you have a great application or a suite of great applications in FM, that could convince people, that could get the ball rolling and could eliminate many of the barriers that we were talking about. When we say our people, they don't know languages, they don't have digital skills, but they all use WhatsApp for planning a family trip, and they all share on all social platforms. So it's not the real issue that they're not digitally native, it's that the applications that we make are too cumbersome or not exciting enough or not easy enough. So having a great AI application that convinces the adopters that service as an example, that would be a great thing to foster the ecosystem." (C3)

> "I think another suggestion is that, maybe technology or hardware. If the maturity level is going faster and faster and the cost can be lower, it will be adapted much faster. So there are more cheaper hardware to be used more in the facility management industry. That's what I tried to say." (C6)

A compelling AI application in facility management (FM) could overcome barriers related to digital skills and language. In addition, the rapid advancement and decreasing costs of technology and hardware can accelerate adoption in the FM industry, making it more accessible and widespread.

5. Discussion

5.1 What are the barriers and drivers for Facility Management to adopt AI?

The integration of AI in the FM industry is an unavoidable progression, fueled by its substantial benefits and the global movement towards technological innovation. Our research identifies four major driving factors and six critical challenges impacting the adoption of AI within the FM sector.

Inevitable evolution

AI integration is an inevitable trend in the FM industry due to its substantial benefits and global trends driven by technological advancements.

Firstly, interviewees highlighted the role of AI in reducing costs and increasing operational efficiency. Making decisions based on a data-driven approach can substantially lower operational costs. This point is further validated by mentioning a study from Carnegie Mellon University, which illustrates AI's capacity to save a quarter million dollars annually per building, thereby confirming its value in cost-saving strategies.

Secondly, AI plays a crucial role in shaping enriched and personalized occupant experiences in diverse built environments. It facilitates easier and more enhanced experiences for building users, as it can personalize environments to meet individual needs, leading to increased user satisfaction. Respondent shared that the vision for AI in FM is to impact built environments globally, improving occupant experiences regardless of the type of building or tenant. This reflects AI's potential to enhance experiences across various occupant categories, indicating its significant role in creating universally enriched user experiences.

Thirdly, AI is seen as a transformative tool in addressing critical sustainability challenges like energy consumption, emission reduction, and decarbonization in the built environment. A significant portion of CO2 emissions comes from buildings, and the application of AI can significantly improve energy consumption efficiency, thus supporting ESG goals and sustainability.

Besides many major benefits that AI can bring to FM, respondents believe that AI integration is a natural and inevitable evolution for FM when global trends are driven by technological advancements. AI integration is a natural and inevitable evolution for FM when global trends are driven by technological advancements. AI's role in FM is seen as part of a broader shift in society towards a digitally driven future, reflecting major changes across various sectors, including those brought about by innovations like ChatGPT of OpenAI.

Drivers

The respondents identify four main drivers to foster AI adoption in FM.

Firstly, a considerable volume of building data remains underutilized, presenting a valuable resource for AI to learn and operate, leading to optimized efficiencies through smart data use. Large amounts of data are generated, collected, and stored related to building automation and management (Sardianos et al., 2020). This has given a fantastic chance to implement AI-big data analytics tools (Quinn et al., 2020).

Secondly, although FM companies are quite lagging behind in technology compared with other industries, they have been working with software companies to implement AI effectively. By partnering with technology partners, FM organizations gain new insights into AI applications and develop their own expertise. This infusion of knowledge strengthens the ability of the FM sector to navigate through the complex world of AI technologies, promoting an environment of innovation and flexibility within the industry.

Thirdly, major international companies in FM are driving the trend by heavily investing in new technologies and focusing on automation and efficiency to combat workforce shortages, with a future shift towards AI-based advisory services. For example, companies like ISS are building in-house IT just to innovate and work on new technologies that can support services.

Lastly, FM's horizontal function across departments is considered an important facilitator for effective AI implementation, as FM is connected to all departments in the company. This allows FM to learn and leverage advancements in AI from other more developed sectors such as banking, insurance, etc.

Barriers

Besides the drivers that foster AI integration, our finding also reveals six significant barriers that FM faces when integrating AI.

Firstly, many interviewees emphasize that legacy technology presents a significant obstacle to AI integration in FM. The existence of disparate and obsolete systems within FM operations. There’s no umbrella system that connects all the fields was particularly noted as a big challenge. The primary obstacles to obtaining and analyzing data on old buildings are outdated technologies and traditional error-prone data collection methods (Jia et al., 2019; Al Dakheel et al., 2020).

Secondly, the lack of awareness and reluctance to change are considered key obstacles to AI adoption. This is due to a limited understanding of AI's capabilities among FM workers, and a lack of younger, tech-savvy talent due to an aging workforce. FM organizational adaptation to new IT solutions encounters not only technical but also psychological hurdles, given the industry's non-technology focus. One interviewee suggests that the long history and size of certain FM companies pose a barrier to AI integration. Daily routines and resistance to change, particularly from long-term employees, can hinder the adoption of AI. As a result, the long history and size of certain companies may create vulnerability to be disrupted by more agile, AI-driven startups.

Thirdly, FM faces challenges related to "Split Incentives", which refers to different perspectives and conflicting interests between different stakeholders. FM companies face a "split incentive" dilemma, where reducing operating costs for clients can paradoxically lower their own revenue. Besides that, there's an internal challenge for facility managers to obtain support and understanding from higher management and other departments in FM companies. They need to convince the whole organization of the potential of AI adoption against the investment cost, adding to the complexity of adopting AI in FM.

Fourthly, implementing AI solutions requires significant change management efforts requiring shifts in work methodologies and stakeholder participation to adapt to new technologies and work patterns. Concerns about AI's impact on job roles and the disruption of traditional staffing models are leading to employee fears about job loss, thereby complicating the shift towards AI-centric operations.

Fifthly, interviewees identify data and privacy concerns as significant barriers to adopting AI in FM. They stress the importance of a comprehensive data management strategy, highlighting challenges in understanding what data to capture and manage, especially in FM's unique context of working on customer sites. One respondent mentioned the example when his team wasn't allowed to connect to client building because of data privacy issues and GDPR. Additionally, the need for understanding individual preferences could limit AI's application in catering to individual preferences due to its potential breach of data privacy and GDPR.

Lastly, the adoption of AI in Facility Management is hindered by a skills gap, including a lack of digital knowledge, frequent staff changes, and a shortage of skilled professionals. This gap not only affects startups but also established FM companies, limiting their ability to provide current services and invest in research or innovation. The barrier is further compounded by the need for staff who are digitally savvy and can effectively operate and manage AI-driven systems, emphasizing the crucial role of skills and resources in successful AI implementation.
In summary, while the integration of AI in FM is marked by its potential to revolutionize the industry in cost-saving, efficiency, and sustainability, it also faces substantial challenges in terms of technology adaptation, workforce readiness, and data management. Overcoming these barriers will be key to realizing the full potential of AI in Facility Management.

5.2 How is the ecosystem of Facility Management influencing AI integration from a Quadruple Helix perspective?

The current state of the Facility Management ecosystem indicates its nascent stage in fostering collaboration among the diverse helices. This highlights the intricacies involved in cooperation across the four distinct domains, necessitating increased interdisciplinary exchanges and the establishment of more effective collaborative frameworks. Moreover, there is a crucial need to focus on creating appropriate incentive structures to promote collaboration among these domains. Encouraging cross-domain dialogue and fostering an environment conducive to collaboration stands as pivotal factors in advancing the integration and alignment of perspectives from government, academia, industry,

and society. This recognition underscores the complexity inherent in harmonizing the efforts of these diverse spheres and emphasizes the imperative for deliberate interventions aimed at facilitating synergistic collaborations.

Our research process revealed a lack of a clear and unified shared vision among the four helices. While there exists alignment in overarching objectives such as achieving EU Sustainable Development Goals (SDGs) and enhancing efficiency with a people-centric approach, discrepancies easily arise among different stakeholders when it comes to specific projects or implementations. Establishing a collective vision would serve to align the efforts of all parties and foster deeper levels of cooperation and innovation.

The experts interviewed agreed that the current facilities management ecosystem is in its infancy. It is mainly manifested by the uneven degree of cooperation between different spirals. This finding also confirms the complexity between the four different areas of cooperation. The FM ecosystem calls for enhanced interdisciplinary communication and the establishment of more effective cooperation frameworks. The FM ecosystem needs more effective collaborative frameworks. Encouraging cross-cutting dialogue and fostering an environment conducive to collaboration are key factors driving the establishment of a facility management ecosystem.

Our study found a lack of a clear, unified shared vision among the four spirals. To be sure, there is a convergence of visions in the broad direction. Examples include achieving the EU Sustainable Development Goals (SDGs) and improving employee efficiency through a greater focus on people-centric approaches. However, this is not the case in specific projects or implementations. Because each spiral represents a different sector, with its own personalized priorities, perspectives, and operational frameworks. As a result, conflicts between goals and methods occur sometimes and even often. Such short-term visions can easily lead to differences among different stakeholders and hinder the realization of collaborative cooperation and cohesive ecosystems.
Deliberately cultivating a shared vision that transcends individual stakeholder interests and sector-specific goals is an important step forward. This unified vision should contain shared values, goals, and a specific roadmap outlining collaborative pathways to achieve the shared goals. We believe that such a collective perspective makes it possible to practically bridge the differences in stakeholder perspectives and promote more cohesive, integrated and harmonious cooperation among different spirals.

Our study also revealed that the current financial framework is insufficient to adequately support the development of "social" participation within the facility management ecosystem. Existing financing tools mainly support traditional innovation or triple helix approaches (Braun & Starkbaum, 2019). The key to meeting this challenge is an overhaul of the FM financial model. Actively encouraging and motivating social participation as an important spiral to participate in the ecosystem is the driving force for the application and integration of AI in FM. In this regard, some experts advocate paid AI-FM services as a potential starting point. These services may act as a catalyst for new financing models and promote the proportion of social participation in the field of facility

management. By rethinking financial mechanisms and establishing supportive frameworks, opportunities can be created for societal stakeholders to contribute positively to innovative initiatives within the ecosystem.

This study highlights the lack of clear guidelines within the existing facility management field that contribute to enhanced cooperation among the four pillars. Heikkinen & Torqui (2023) highlighted the significant impact of guidelines on the approval of innovations in the EU on industrial decision-making. These guidelines may contain standardized processes for collaborative project development and the establishment of platforms that facilitate cross-domain dialogue.

Our study proves that IFMA is an important hub in the field of facility management. Firstly, it actively connects academia and practice to shape industry trajectories. Secondly, it facilitates an integrated professional landscape, emphasizing the importance of Facility Management and AI's transformative role. Thirdly, IFMA used its influence on lobby for the government to be able to engage effectively in change, thereby highlighting its key role in guiding the industry.

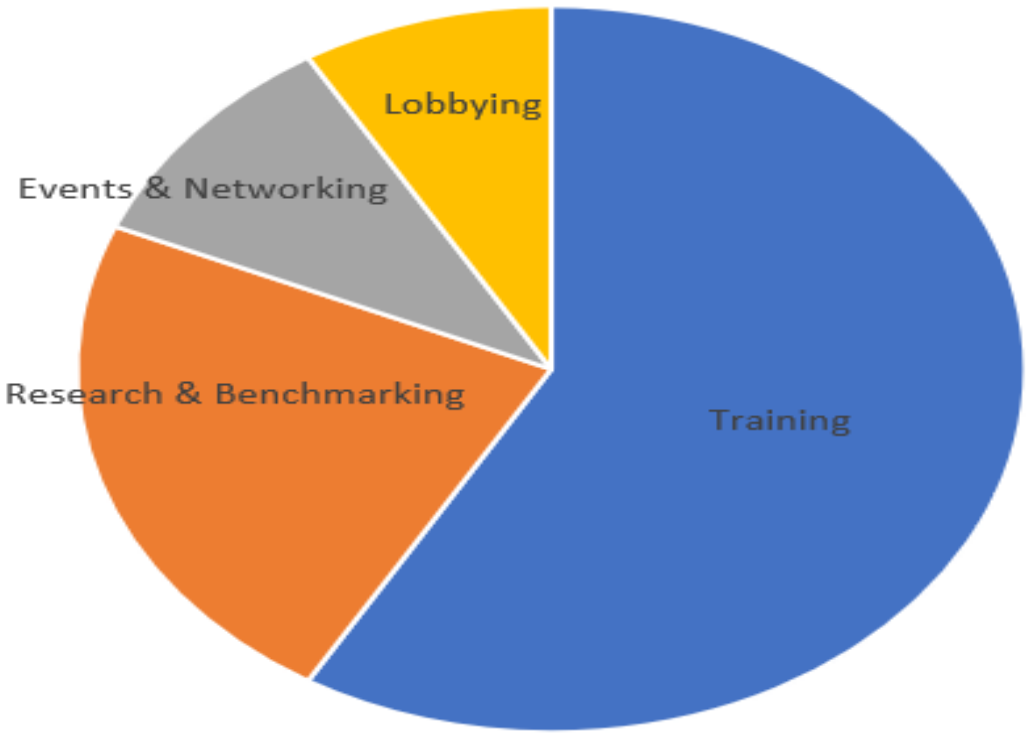

Figure 8: IFMA's Activities

5.3 How to strengthen ecosystem linkages to foster AI integration in Facility Management?

Enhancing the connections among the four stakeholders within the Quadruple Helix Model is crucial for advancing AI integration in FM. The study presents recommendations derived from respondents with diverse backgrounds and viewpoints. These recommendations are organized into five key areas,

underscoring the importance of a collaborative and multi-faceted approach to AI implementation in FM.

Firstly, the majority of the interviewees (five out of seven) identify skill development as the most important solution for AI integration in FM. This underscores the importance of equipping industry professionals with specialized skills and competencies relevant to AI. A notable gap in understanding AI within the FM workforce is highlighted as "people don't know what it is, and how it works", suggesting that a lack of knowledge is a significant barrier to the effective use of AI in daily operations. The interviewees stress the necessity of training programs that can aid FM workers in comprehending the potential benefits of AI for their operations and their organizations.

Secondly, fostering information sharing is ranked as the second priority by six out of seven interviewees. The focus here is on strengthening the linkages between the four components of the Quadruple Helix model, enhancing the collaborative role of different stakeholders in the ecosystem. The interviewees argue that effective information sharing can significantly increase the use and adoption of AI in the market. By fostering a culture of knowledge dissemination, the understanding and valuation of AI across various sectors are expected to improve, thereby driving its wider use and innovation.

Thirdly, the regulatory framework is seen as a catalyst for innovation, especially in the integration of AI. It is viewed as a fundamental element that not only kickstarts but also accelerates AI innovations in various industries. This impact is significant for businesses, as it drives more innovation and strengthens the ecosystem. It is noted that without a conducive regulatory framework, industries risk falling behind in technological advancements. Besides that, the respondent also emphasizes that the industry bears a responsibility to actively shape this dynamic and innovative future through its regulatory practices.

Fourthly, government support is considered crucial in stimulating AI integration. The example of the Czech Republic is highlighted, where government initiatives have successfully stimulated AI integration without being overly directive or restrictive. This suggests that thoughtful government support can play a pivotal role in advancing AI integration in a balanced and effective manner.

Lastly, many interviewees suggest that good AI applications could play a significant role in advancing AI integration in FM. These applications should be user-friendly and engaging to overcome the barriers related to digital skills and language. Moreover, it is believed that advancements in technology and more affordable hardware could accelerate AI adoption in the FM industry.

In conclusion, these recommendations provide an overview of solutions for enhancing AI integration in FM by strengthening the ecosystem linkages of the Quadruple Helix Model. It emphasizes the critical importance of skill development and fostering information sharing as the most important solutions. The total five solutions are identified by respondents from varied backgrounds, collectively forming a strategic blueprint for overcoming existing barriers and unlocking the full potential of AI

in the FM sector, ultimately leading to more innovative, efficient, and forward-thinking industry practices.

6. Conclusion

FM is all over the place and plays a vital role in enhancing the well-being of people and the productivity of businesses. Its development has been influenced by new technologies, with AI being one of the most powerful tools. However, the FM industry is considered to be lagging behind and needs to speed up to catch up with this inevitable evolution.

Data privacy is one of the most pressing challenges that FM faces when implementing AI technologies. Additional studies are necessary for the industry to gain better insights and address the issue effectively.

The FM ecosystem is still in the early stages when it comes to collaboration to foster AI integration among four components of the Quadruple Helix model - government, industry, academia, and society. However, building and developing the ecosystem is a continuous process, and by strengthening the linkages in the ecosystem, FM can effectively foster AI integration.

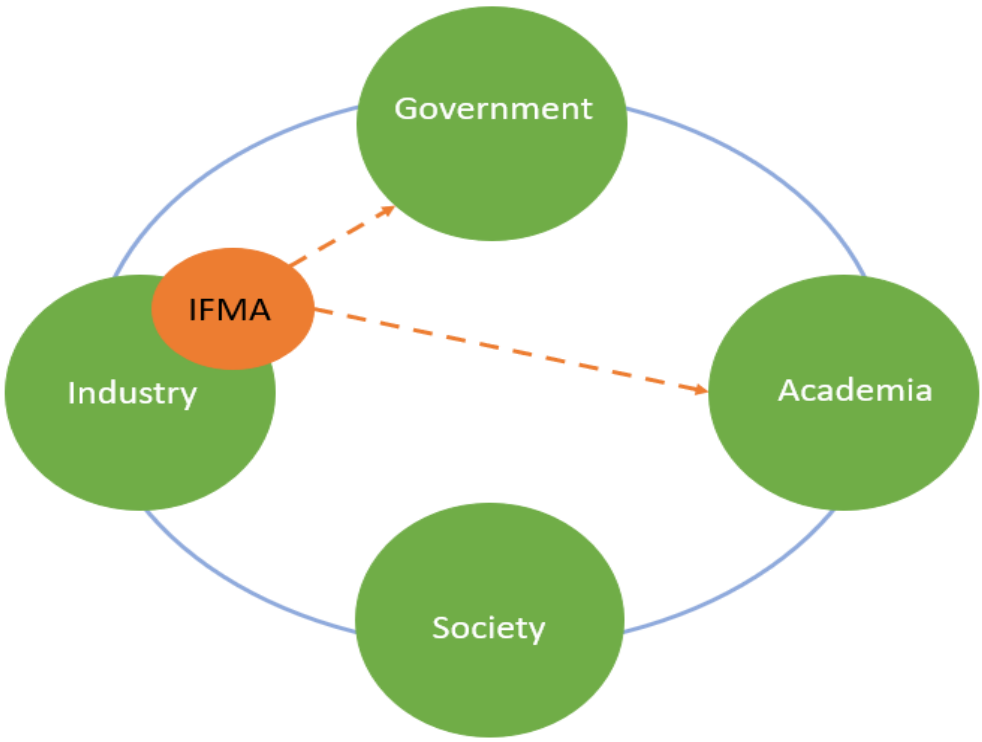

Figure 9: Quadruple Helix Model for FM industry

The government plays an important role in setting up a clear regulatory framework and standards to guide the FM industry to develop sustainably. This requires the involvement and efforts of the industry, especially from industry associations like IFMA, to lobby the government to get more support and build a future trajectory.

There's an urgent need to fill the skill gap in the FM industry, which can be done through education, training and life-long learning. There should be more initiatives dedicated to FM learning and training, not only coming from higher education institutes but also from the industry itself. Besides that, better communication and cooperation between academia and industry is crucial to close the gap between theoretical knowledge and practical application. While academia should share more practical scientific research with the industry, the industry should provide valuable tacit knowledge for academia to enhance research and education quality.

Sustainability is a topical issue that is influencing societies worldwide. Governments have set sustainable development goals, and the public is demanding more environment-friendly solutions. AI has the potential to be one of the key enablers for FM to improve and develop in a sustainable way.

IFMA's vital role as an anchor in the FM ecosystem is emphasized. It reinforces the connections in the ecosystem while promoting AI integration in this sector. It bridges the gap between industry and academia while lobbying the regulations with the government due to its influential role. Besides that, it's dedicated to raising public awareness about the importance of FM and educating FM professionals with updated knowledge and skills about AI. This multifaceted approach highlights IFMA's crucial role in shaping the future direction and leading the FM industry moving forward.

6.1 Theoretical Implications

Our dissertation examines practice from a quadruple helix model perspective and sheds light on the main barriers to AI adoption in the facility management (FM) industry. These findings have important implications for future research and will guide the academia to conduct a deeper exploration of specific elements and solutions to innovation problems.

Firstly, building a customized quadruple helix structure suitable for the FM industry is the focus. Given the broad industry scope of FM and the constraints imposed on its development by its relationship with demand organizations, it is imperative to explore ways to maximize stakeholder participation and minimize incentive segmentation between different pillars. Future research efforts could delve into more efficient interaction models tailored specifically for FM, while fostering incentive financial frameworks. These initiatives aim to promote the rapid and orderly advancement of the application and integration of AI in the field of FM.

In addition, a potential research path lies in advancing the implementation of AI solutions in FM within the framework of laws and regulations. This requires extensive cross-disciplinary and cross-field collaboration. In turn, experience is summarized from complex, representative case studies to facilitate knowledge sharing among stakeholders.

Finally, a forward-looking area for future research is to target an in-depth analysis of "society" participation in the development of FM. Understanding the dynamics of social engagement and its impact on FM progress is an area worth exploring. This direction can provide insights into strategies

to promote enhanced "society" participation. It has the potential to unlock the full potential of AI-driven FM advancements for the benefit of the industry.

6.2 Managerial Implications

Based on the findings, our research comes up with some solutions that can be implemented. Firstly, it's necessary to raise awareness about the role of FM and AI to the public. Students should be given more information about the FM profession and its important role in society. This will encourage more skilled young workers to join the FM industry and help combat the labor shortage situation. Additionally, current FM workers should be able to receive the necessary training to understand and leverage AI solutions. This will help reduce the reluctance to change and equip them with the necessary skills to use AI tools effectively, thereby fostering the integration of AI in the FM industry.

The government can take the lead in the development of frameworks and policies that support the adoption of AI in FM, contributing to sustainable goals. It can encourage private companies and educational institutions to collaborate by offering incentives and financial support mechanisms. This approach would reinforce relationships between the government, industry, and academia, encouraging joint efforts.

The industry, including industry associations like IFMA, can play a significant role by collaborating with the public sector, educational institutions and society to create AI solutions specifically designed for FM. The industry should work more closely with academia, providing them with more practical knowledge and business cases and guiding research direction. It can further support academic institutions by offering resources, mentorship programs, and internships, enabling students to acquire hands-on experience in AI. Additionally, FM organizations can support researchers with funding in order to attract more research related to AI in FM. Besides that, it's important for FM companies to involve the public in the process of AI innovation. A good application should be user-centric and conscious of data privacy.

IFMA should strengthen its anchor role in strengthening the FM ecosystem, fostering AI integration. It should try to stay ahead in AI training, ensuring FM workers are equipped with the necessary skills and knowledge to leverage AI in their operations. Besides that, IFMA should continue to lobby and advocate with politicians to influence policies and standards that will govern and support the FM industry in a sustainable way. By effectively demonstrating the significance of FM roles, IFMA can persuade governments to allocate more focus and resources to this sector. In addition, it is important for IFMA to engage with universities to ensure that FM training programs are closely aligned with industry realities. By doing this, IFMA can contribute to the development of a new generation of FM experts who are well-prepared to meet the current and future challenges of the industry.

Academia plays a critical role in preparing the next generation of professionals with essential AI skills and knowledge. These educational institutes can partner with the government and the industry to develop courses and training programs that meet industry requirements. Furthermore, they have the capability to set up workshops, conferences, research centers or innovation hubs, which would

greatly encourage cross-disciplinary collaboration and knowledge sharing among academia, government, industry and society.
Society is the central focus of any AI invention. Every person has the potential to influence and shape industry trends. Individuals can advocate for higher standards in AI applications, not only in the workplace but also in their personal lives. In the workplace, individuals can advocate for the use of AI to streamline processes, enhance productivity, and foster a culture of technological innovation. They can encourage their employers to adopt AI solutions, which not only improve efficiency but also adhere to ethical standards. At home, the demand for AI can take the form of seeking out and preferring smart technology solutions that enhance daily living. As society becomes more accustomed to and demanding sophisticated AI applications in everyday life, it sets an expectation for industries like FM to innovate and adopt AI solutions.

In summary, this research provides some suggestions to foster AI integration in FM, emphasizing the urgent need to raise awareness and fulfill the skill gap in the FM sector, and advocating for government-led policy development to support AI adoption. It highlights the crucial roles of FM organizations and IFMA in fostering practical applications and aligning educational programs with industry needs. Society plays an important role in advocating for ethical AI applications, adding motivation to push the industry toward sustainable, user-centric solutions.

6.3 Limitations and Further Research

In conducting this study, the researchers found a number of limitations. First of all, AI technology is developing at a rapid pace, and news about AI is refreshing our understanding every day. The New York Times recently sued OpenAI. How this will affect the future of AI technology is unknown. Also a few days ago, OpenAI's GPT store officially went live. This is a new online platform that allows anyone to create an AI Agent based on their own knowledge base in natural language (without writing any code). What kind of AI revolution will this bring? We'll just have to wait and see. It is clear that the unpredictability of such events limits our current understanding of the trajectory of AI technology and its implications for future research.

The three key building blocks of AI are data, algorithms and computing power. These three elements have been developed to varying degrees in different countries. And the degree of development of the FM industry also varies from country to country. Our research sample is drawn only from Europe and the United States (one expert), and it is unfortunate that there is no way to obtain different views from more countries. Future research should strive to expand the sample to cover perspectives from different countries and regions to gain a more comprehensive and nuanced understanding of AI convergence in FM. This extension will enable a more robust and globally representative analysis of AI-related challenges and potential in FM.

Understanding the government's perspective and its strategy regarding promoting improved interaction among the four spirals is critical to driving the adoption of AI within the FM industry more broadly. This paper cannot obtain the attitudes and opinions of government personnel on the further

integration of AI into FM. This is another limitation. Subsequent research can further explore the government's attitude and opinions on the deep integration of artificial intelligence and FM.

6.4 Recommendations

Life-long learning and FM training

For current or potential FM employees, it is crucial to continuously learn new skills (especially AI tech) to keep pace with the times for the development of the whole industry.

Abundant interactions between academia and FM industry

Academia should work more closely with industry to provide new technologies and bridge the gap between theory and practice. On the other hand, industry should actively strengthen its ties with academia, providing resources, mentorship programs, and internship opportunities, which will attract more research related to AI application and integration in FM.

Creating collaborative innovation strategies to engage FM users

The collective innovative power of society has not been exploited in the FM industry. From the experience of other fields, the driving force of society may bring unlimited possibilities for AI integration in FM.

Adapting regulations for AI advancement and FM industry standards

Revise regulations to adapt to the progress of AI, giving full consideration to user interests and privacy. And comply with evolving industry standards in the field of facility management.

Continue to expand and deepen the anchor role of IFMA in the worldwide

Through research, we found that IFMA closely linked the FM industry and the other three pillars through various interactions in the FM ecosystem, thus promoting the development of the industry. The role of IFMA must continue to flourish.

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Addendum 1: Interview Questionnaire

RQ1. Opportunities and challenges for Facility Management (FM) companies to adopt AI effectively:

- Is AI integration happening in your organization? Yes/ No

- Why it's important for FM companies to integrate AI?

- In your opinion, what are the main enablers and barriers for FM companies to integrate AI?

RQ2. Facility Management (FM) ecosystem:

1. Roles of stakeholders in the Facility Management (FM) ecosystem in AI integration

1.1 Government

- What are the laws/ rules affecting (positively/ negatively) the AI integration in FM?
- Is the government providing financial or real estate or built environment incentives that will promote the FM sector's adoption of AI?
- What measures does the government take to increase society/ private/business/ sector demand for AI integration?
- What does the government do to foster academia, FM industry, and the general public to work together to integrate AI in FM?

1.2 Academia

- How does academia contribute to the R&D of AI in FM?
- How does academia collaborate with FM companies in AI integration?
- Are curricula/programs changing in favour of providing FM with a sufficient talent pool?
- What function does academia have in encouraging government agencies, FM industry, and the general public to work together to integrate AI in FM?

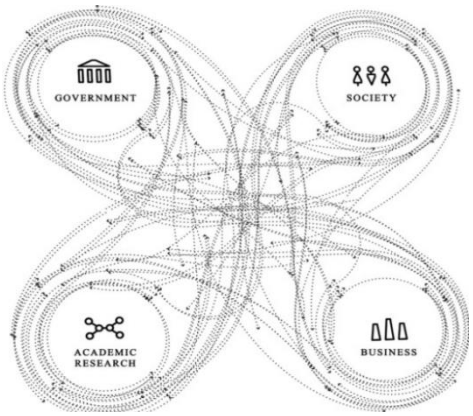
1.3 Industry

- How is the FM industry currently adopting AI? (Slow/ Fast)
- What are the most popular AI technologies adopted? Why?
- Are there industry-specific best practices or case studies related to successful AI integration in FM? What lessons can be learned from industry leaders?

1.4. Society

- How does the general public respond to AI integration in FM?
- To what extent are end users (building occupants, tenants, etc…) engaged in AI-driven FM practices?
- How is society contributing to the discussion on sustainability and ethical considerations in AI usage within the FM field?

2. Impact of FM ecosystem on AI integration



- How do the ***four components*** (academia, industry, government, and society) involved within the FM ecosystem ***influence the pace and direction*** of AI integration in FM?

RQ3. Strengthening ecosystem linkages to foster AI integration:

In your opinion, which are the ***top three options*** that can make major impacts in ***strengthening ecosystem linkages*** to foster AI integration?

a. **Skill Development**: promote ongoing education and the enhancement of skills for the workforce about AI integration within the FM community/association.

b. **Create Innovation Hubs:** establish physical or virtual innovation hubs where all four entities can come together to brainstorm, prototype, and develop innovative solutions.

c. **Foster information Sharing:** promote the exchange of information and knowledge between the four ecosystem components (creating centralized platforms for data sharing, research findings, and best practices).

d. **Government Support:** governments can create policies that support and incentivize collaboration. (grants, tax incentives, or regulatory frameworks that promote joint ventures and research).

e. **Industry Regulatory Framework**: encourage sustainable development in FM by emphasizing ethical and legal compliance related to AI (Ex: data privacy...)

f. **Public Engagement**: involve users and stakeholders (suppliers...) in decision-making processes related to AI integration in FM.

g. **Other Suggestions**

Please elaborate your choices

Addendum 2: Chapter Separation

CHAPTER	**WRITER**
PROBLEM STATEMENT	YANG LIN
LITERATURE REVIEW	DOAN DI HUONG GIANG & YANG LIN
RESEARCH METHODOLOGY	DOAN DI HUONG GIANG & YANG LIN
FINDINGS	DOAN DI HUONG GIANG & YANG LIN
DISCUSSIONS	DOAN DI HUONG GIANG & YANG LIN
CONCLUSIONS	DOAN DI HUONG GIANG & YANG LIN