Barriers to Digital Transformation in Facilities Management: Insights from a Developing Country

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Abstract: Digital transformation (DT) is increasingly recognised as essential for enhancing operational efficiency, sustainability and competitiveness in facilities management (FM). However, its adoption, particularly in developing countries, remains slow due to persistent barriers. This study adapted the technology-organisation-environment (TOE) framework to investigate the fundamental barriers hindering DT in the FM sector by drawing on insights through semi-structured interviews with senior executives in FM organisations. Notably, the analysis uncovered 14 major barriers, categorised into the technological, organisational, process, people and financial factors. These findings revealed significant gaps in areas like organisational preparedness, technological integration and skill development within FM, contributing to the sector's slower progression in DT compared to other industries, such as healthcare and manufacturing. This study contributes to the growing body of knowledge on DT in FM by providing empirical evidence of the barriers specific to developing countries. It also deepens the understanding of the socio-technical challenges holding back DT in the sector. The findings highlight the urgent need for tailored strategies to help FM organisations overcome these obstacles, enabling FM stakeholders to enhance service delivery, drive operational efficiency and align with global digital trends.

Keywords: Facilities management, Digital transformation, Barriers, Developing country, Innovation

INTRODUCTION

The facilities management (FM) sector has evolved significantly over the decades. It has transitioned from its origins as a reactive and task-oriented discipline to a proactive and strategic function. Historically, FM was primarily concerned with routine maintenance and operational tasks that focused on minimising costs and ensuring basic functionality (Atkin and Brooks, 2021). Nevertheless, as buildings became more complex and user needs diversified, FM began incorporating advanced methodologies and tools to address broader objectives such as sustainability, space optimisation and asset

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longevity (Marmo et al., 2019; Akinshipe, Aigbavboa and Anumba, 2022). This evolution has been particularly significant in developing countries, where rapid urbanisation and economic growth have placed unprecedented demands on infrastructure. Thus, additional efficient FM practices are required to ensure long-term viability (Ali et al., 2023).

FM is now recognised as a cornerstone of effective building lifecycle management, encompassing a wide range of activities, including maintenance, asset management, space planning and contract management (Aliu and Ariff, 2019; Konanahalli, Marinelli and Oyedele, 2022). Accordingly, the FM phase spans the longest duration in a building's lifecycle (Salman and Ahmad, 2023), with research indicating that it accounts for 50% to 70% of total annual facility operating costs (Tang et al., 2019). Furthermore, the operation and maintenance phase contributes over 80% of a building's total lifecycle costs, far exceeding the combined costs of the design and construction phases; this collectively accounts for less than 15% (Hoang et al., 2020; Altohami et al., 2021). Together, these figures highlight the pivotal role of efficient FM practices in ensuring that facilities remain functional, cost-effective and environmentally sustainable throughout their operational lifespan.

Despite its significance, the FM sector has faced persistent challenges over the past decades that have impeded its growth and competitiveness. Challenges such as inefficient resource allocation, low productivity and fragmented workflows remain prevalent compared to more technologically advanced sectors like manufacturing and finance (Hauashdh et al., 2021; Lee, Irisboev and Ryu, 2021). These challenges are often exacerbated by the continued reliance on conventional methods, including paper-based processes, manual documentation and siloed data management systems (Yaqot and Al-Ramadan, 2024). Such outdated methods lead to slow decision-making, increased operational costs and limited access to real-time performance data (Durdyev et al., 2022).

Digital transformation (DT) entails leveraging digital technologies to reshape business models and create new value-adding opportunities within an organisation and its environment (Nadkarni and Prügl, 2021; Verhoef et al., 2021). This offers a transformative solution to these long-standing issues. Following this, by leveraging advanced technologies such as the Internet of Things (IoT), artificial intelligence (AI), cloud computing and building information modelling (BIM), DT can enhance productivity, streamline operations and improve service delivery in FM (Dahanayake and Sumanarathna, 2022). For example, smart FM systems powered by IoT have been successfully implemented in smart cities to monitor building conditions remotely, ensuring proactive maintenance and energy optimisation (Atta and Talamo, 2020b; Villa et al., 2021). However, despite the promising potential of DT to enhance FM operations, its adoption within the sector remains significantly limited (Adhikari, Hoffman and Lietke,

2019). This is largely due to a range of persistent challenges that hinder effective uptake. Compared to related sectors like architecture, engineering and construction, FM has slowly integrated digital innovations (Støre-Valen, 2021; Song and Li, 2022). This disparity is particularly pronounced in developing countries, where contextual challenges further complicate the DT agenda (Amos, Au-Yong and Musa, 2020; Mehmood et al., 2023).

Prior studies have identified several barriers impeding DT adoption in FM. For instance, Elyasi, Bellini and Klungseth (2023) explored the use of digital twins in FM during the operational phase. The authors highlighted barriers such as resistance rooted in organisational culture and the absence of robust information management frameworks. Similarly, Adhikari, Hoffman and Lietke (2019) and Marocco and Garofolo (2021) identified fragmented information systems, limited technical skills and a lack of validated real-world applications as significant hindrances. Meanwhile, Zhan et al. (2023), in a study focused on Singapore, identified poor data management, high initial implementation costs and cybersecurity risks as predominant challenges in adopting smart FM technologies. Furthermore, Durdyev et al. (2022) reported similar challenges in New Zealand, emphasising high costs and limited expertise with advanced tools such as BIM. While these studies offer valuable insights, they predominantly focus on developed economies with well-established infrastructure and technological capabilities. This leaves a critical research gap in understanding the barriers faced by FM practitioners in developing countries, where socioeconomic, cultural and technological contexts differ significantly. The FM sector in these regions faces unique challenges that are rarely addressed in existing literature.

In response to this gap, the present study investigated the fundamental barriers to DT in the FM sector, specifically focusing on Malaysia as a representative case of developing countries. Anchored in the technology-organisation-environment (TOE) framework, this study offered a contextualised understanding of the factors that impeded the effective integration of DT into FM practices. Concurrently, the insights gleaned from this study can serve as a guiding compass for FM practitioners, industry leaders and policymakers by highlighting priority areas that require interventions. Furthermore, an in-depth empirical understanding of these barriers could pave the way for developing tailored strategies and best practices to overcome these obstacles and fully harness the benefits of DT in FM for developing economies.

LITERATURE REVIEW

Theoretical Background

The TOE framework proposed by Tornatzky, Fleischer and Chakrabarti (1990) is widely acknowledged for its applicability in explaining the adoption of technological innovations across diverse organisational settings. It highlights that an organisation's decision to adopt a particular technology is influenced by its technological, organisational and environmental context (Qatawneh, 2024). The technological context addresses the characteristics of an organisation's digital tools and infrastructure, such as their complexity, compatibility and perceived benefits (Adade and De Vries, 2024). Meanwhile, the organisational context captures internal factors, including top management support, structure, scope, size and existing capabilities (Nguyen, Le and Vu, 2022). At the same time, the environmental context considers external influences, such as regulatory pressures, market dynamics and competitive forces (Zhong et al., 2024).

Despite the TOE framework's potential and broad scope, its primary components and constructs vary across different contexts (Shukla and Shankar, 2022). As a result, the framework needs to be modified to fully address the research question in some context. For instance, Bryan and Zuva (2021), in their study on adopting BIM, extended the TOE framework by incorporating economic factors such as return on investment (ROI) and costs related to training and consultancy. They discovered that these elements did not align with the conventional TOE dimensions. Similarly, Adade and De Vries (2024) introduced the stakeholder dimension to better understand the adoption of digital technologies for collaborative planning. Ahmad and Siraj (2023) also proposed an extension of the TOE framework by adding individual factors, recognising its importance in e-commerce adoption.

Figure 1 displays the barriers related to people, processes and finance in the context of FM's implementation of DT that emerged as key considerations. Prior studies have demonstrated that internal organisational factors related to people often constituted the most immediate and persistent barriers to successful digitalisation. This is particularly true in operationally intensive sectors like FM (Xiang et al., 2022). Moreover, FM is a highly internal-facing function. Its primary focus lies in improving internal processes such as enhancing building performance, managing costs and extending asset lifecycles. Specifically, these objectives are shaped by internal capabilities rather than external environmental triggers. Therefore, after a thorough theoretical review and in line with the study's objective, five dimensions, namely, organisation, technology, people, process and finance, were identified as the most suitable to comprehensively investigate DT barriers in FM, mainly in a developing economy setting.

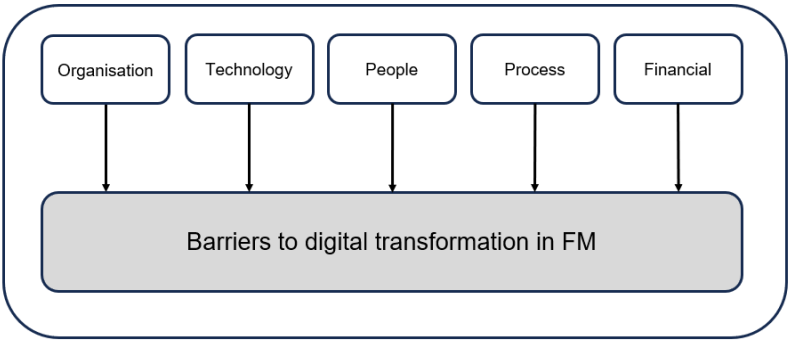

Figure 1. Conceptual framework

Digital Transformation Barriers

In the pursuit of DT, organisations encounter challenges that necessitate careful consideration and strategic management. These challenges stem from the complexities of digitalisation and the need for adaptation to new technologies, processes and cultural shifts (Saarikko, Westergren and Blomquist, 2020). Thus, identifying and effectively addressing these barriers is crucial for the success of DT initiatives (Cichosz, Wallenburg and Knemeyer, 2020; Parola et al., 2020). Table 1 presents an overview of the diverse barriers organisations face across technological, organisational, process, people and financial dimensions during DT.

Mahmood, Khan and Khan (2019), in their comprehensive literature review referring to 55 sources, identified the lack of an effective strategy as a significant barrier to DT. This deficiency often leads to misaligned objectives and fragmented efforts, impeding the coherent integration of digital technologies into organisational processes (Benevento et al., 2023). Furthermore, Vial (2019), drawing on 35 sources, identified inertia as a notable obstacle to DT. Notably, inertia is pertinent in situations where existing resources and capabilities act as obstacles to disruption, highlighting the significance of path dependence as a constraining force in technological innovation. Additionally, Vial (2019) noted from an analysis of 40 sources that employee resistance demonstrated when disruptive technologies were introduced in the organisation was another significant barrier to DT. This resistance largely stems from employees' fears of job insecurity, driven by their lack of necessary digital skills or concerns about being replaced by technology (Cieslak and Valor, 2025).

Table 1. Digital transformation barriers

Barrier Type	Barrier	Source
Organisational	Inappropriate organisational structure and culture	Agrawal, Narain and Ullah (2020); Tijan et al. (2021)
	Lack of digital strategy	Mahmood, Khan and Khan (2019); Agrawal, Narain and Ullah (2020)
	Lack of industry-specific guidelines	Agrawal, Narain and Ullah (2020); Tijan et al. (2021)
	Lack of leadership and top management support	Kane et al. (2018); Agrawal, Narain and Ullah (2020)
Technological	Type of technology	Agrawal, Narain and Ullah (2020)
	Cyber security issues	Khanzode et al. (2021); Marocco and Garofolo (2021); Konanahalli, Marinelli and Oyedele (2022); Turk et al. (2022)
	Lack of standardisation	Schumann et al. (2017); Gong and Ribiere (2021); Olanipekun and Sutrisna (2021)
	Poor data management	Gerrish et al. (2017)
Process	Inflexible business process	Agrawal, Narain and Ullah (2020)
	Complexity of decision-making processes	Agrawal, Narain and Ullah (2020)
People	Inertia and resistance	Vial (2019); Vogelsang et al. (2019)
	Lack of digital skills and talent	Agrawal, Narain and Ullah (2020); Marocco and Garofolo (2021); Tijan et al. (2021)
	Fear of job loss	Vogelsang et al. (2019)
	Lack of digital vision and sense of urgency	Agrawal, Narain and Ullah (2020)
Financial	Lack of clear economic benefits	Heilig, Lalla-Ruiz and Voß (2017); Raj et al. (2020)
	High investment costs	Gausdal, Czachorowski and Solesvik (2018); Agrawal, Narain and Ullah (2020); Raj et al. (2020); Perno, Hvam and Haug (2022)
	Lack of financial resources	Vogelsang et al. (2019)
	ROI concerns	Leipzig et al. (2017)

Moreover, it has been frequently cited that people constitute the major obstacle to DT (Agrawal, Narain and Ullah, 2020). Raza et al. (2023) observed that a common issue with people was the lack of digital vision and sense of urgency. Considering this, Sharma and Lenka (2024) highlighted the

concept of "competency traps", where employees' reliance on past successes impeded adaptation to new methods. Meanwhile, Gkrimpizi, Peristeras and Magnisalis (2023) documented the difficulty organisations faced in changing the mindsets and beliefs of people. At the same time, Vogelsang et al. (2019) identified individual barriers, such as fear of job loss, while Chahid et al. (2025) emphasised the lack of digital competencies in organisations. Managerial and cultural threats to DT implementation, including inadequate leadership and insufficient top management support, were also widely reported (Lammers, Tomidei and Trianni, 2019).

Facilities Management and Digital Transformation

DT is increasingly becoming a vital area within the FM sector, offering significant opportunities for innovation and advancement. Historically, DT studies specific to FM were sparse, yet the sector increasingly recognises the necessity for transformative business practices. Studies have highlighted key drivers of DT in FM, including evolving client needs, competitive pressures, the shift towards integrated data ecosystems and the imperative for enhanced value creation (Atta and Talamo, 2020a; Codinhoto et al., 2021). The advent of the COVID-19 pandemic further underscored the urgency for DT in FM, notably to support remote engagement and operations (Kıyıklık, Kuşakcı and Mbowe, 2022). As a result, the integration of technology and the focus on DT have become foundational for future growth. This, in turn, enables FM to overcome disruptions in global supply chains, address talent shortages and mitigate financial pressures (IFMA [International Facility Management Association], 2024a).

The growing focus on sustainability and environmental stewardship propels the FM sector to embrace digital technologies. Traditional FM systems such as computerised maintenance management systems (CMMS), computer-aided facility management and building management systems, often referred to as building automation systems, have long played a critical role in managing facility operations. This includes streamlining maintenance tasks, optimising building performance and automating routine processes (Wijeratne et al., 2024; Aliu et al., 2025). However, with the rapid evolution of digital technologies, these conventional systems are being enhanced and integrated with more advanced solutions. This has driven a sector-wide shift marked by the adoption of disruptive technologies such as BIM, IoT, big data analytics, digital twins, cloud computing and AI (Codinhoto et al., 2021).

Technologies are revolutionising FM, offering unprecedented opportunities to enhance operational efficiency, sustainability and performance globally. For instance, BIM facilitates real-time, accurate modelling of buildings and assets (Altohami et al., 2021). According to Dahanayake and Sumanarathna (2022), IoT-BIM integration offers a beneficial platform for DT in FM, optimising

the effectiveness and efficiency of building operations. Furthermore, this transformation has significantly improved the lifecycle management of facilities by enabling accurate resource planning, streamlining workflows and enhancing project outcomes. Similarly, the integration of IoT-enabled smart sensors and big data analytics provides the ability to monitor and analyse real-time data, leading to informed decision-making and optimised resource allocation (Yang and Bayapu, 2019; Boje et al., 2020). AI further augments these capabilities by automating decision-making processes, a feature increasingly vital in high-stakes FM environments. According to Bechina and Arntzen (2022), systems driven by AI can process and analyse vast amounts of data from various sources in real-time, to provide actionable insights and recommendations for facilities managers. Conversely, in the context of energy management, studies have demonstrated that IoT sensors and big data analytics can identify energy usage patterns and recommend changes to minimise waste (Zekić-Sušac, Mitrović and Has, 2021). Additionally, AI-powered systems can predict equipment failures and schedule maintenance during planned downtime, reducing costly disruptions and unexpected repairs, or they can analyse occupancy trends to optimise space utilisation (IFMA, 2024b).

Moreover, digital twins, which create dynamic virtual representations of physical assets, have emerged as a solution for enabling real-time data acquisition, transfer, analysis and utilisation to improve decision-making in smart FM (Hakimi, Liu and Abudayyeh, 2024). According to Delgado and Oyedele (2021), digital twins offer significant benefits for optimising structural health monitoring, streamlining inspections and improving fault detection and diagnostics. For example, Lu et al. (2020) demonstrated how a digital twin-based anomaly detection system, integrated with an extended industry foundation class data structure and Bayesian change point detection, enhances asset monitoring. In particular, this system enables continuous, automated anomaly detection in heating, ventilation and air conditioning systems, addressing the need for more efficient operation and maintenance strategies in the FM sector. Another critical area is the application of mixed reality (MR), virtual reality (VR) and augmented reality (AR) technologies in FM. Following this, Salman and Ahmad (2023) highlighted the potential of these tools for training, simulation and facility walkthroughs, enhancing interactivity and user experience in FM. On a similar note, El Ammari and Hammad (2019) proposed a BIM-based MR framework integrating VR and immersive augmented virtuality (IAV). It enhances FM by streamlining field tasks, enabling real-time data visualisation and improving collaboration between field workers and office managers. Collectively, the approach supports DT by boosting efficiency, decision making and communication in FM operations.

Despite the increasing recognition that DT can serve as a critical game-changer in FM, the architecture, engineering and construction sector's current practices remain predominantly outdated with limited technology integration (Aliu et al., 2025). A significant challenge lies in the gap between the potential of digital tools and the realities of their implementation. For instance, facilities managers still spend a considerable portion of their time on non-productive tasks, such as visualising models and searching for and validating information, due to insufficient information support (Sampaio, Costa and Flores-Colen, 2022). The lack of interoperability between various FM information systems further complicates this challenge. Matarneh et al. (2019) highlighted that FM teams struggle with information management. Furthermore, industry expectations are increasingly outpacing the capabilities of FM teams. The IFMA's White Paper, "Leading Digital Transformation in the Facilities Management Industry" (2023), accentuates this growing disparity where organisations increasingly expect FM teams to lead or support enterprise-wide DT efforts. Nevertheless, many lack the requisite expertise and resources to meet these elevated demands (IFMA, 2023). This disconnect illustrates a critical area for research and intervention. As the FM sector moves forward, a comprehensive approach to DT adoption will be essential to overcome existing barriers, optimise processes and unlock unprecedented levels of innovation.

METHODOLOGY

Research Approach

Considering the limited availability of empirical research on DT within the FM sector and that the study aimed to delve into various aspects rather than subject them to quantitative testing, this study adopted an exploratory qualitative research design to investigate the topic. The research approach followed a two-phase strategy. First, a thorough literature review to identify prevalent barriers was conducted to discern recurring patterns relying on the TOE framework. This phase informed and streamlined the analysis for the subsequent qualitative phase. In the second phase, semi-structured interviews were conducted with qualified experts from the industry. The interviews were designed to provide in-depth, context-specific insights into the barriers identified in the first phase. A flowchart illustrating the research phases is presented in Figure 2.

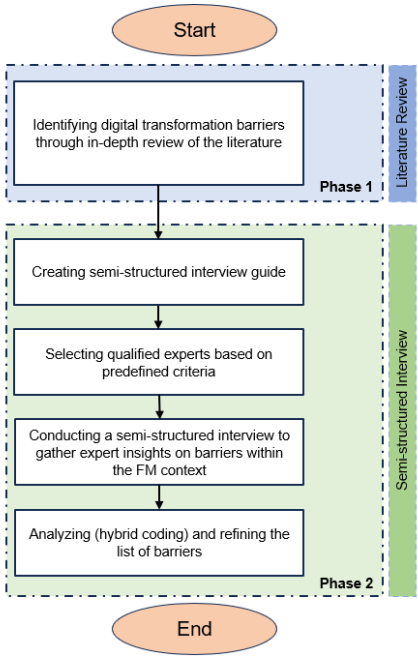

Figure 2. Research methodology flowchart

Respondent Selection

Considering the exploratory nature of this study and the need to contextualise the topic within the FM sector, the study respondents were selected through a purposive sampling strategy (Chomistriana, Mulyono and Najid, 2024). Consequently, respondents were selected based on several predefined criteria to ensure their suitability for contributing meaningful insights. These criteria included at least 10 years of experience in the FM sector and senior roles involving strategic decision-making and oversight of DT initiatives. Additionally, respondents were required to have substantial involvement in DT projects, including leading or coordinating initiatives such as BIM integration, IoT deployments and the adoption of big data analytics and AI in FM. At the same time, relevant qualifications, such as certifications from recognised professional bodies like the Construction Industry Development Board (CIDB), were also considered. Respondents from both public and private FM sectors were selected to provide diverse perspectives on barriers to DT across different operational contexts. Accordingly, potential respondents were identified through professional networks, industry associations and referrals, with invitations sent via email detailing the study's objectives and confidentiality measures.

When determining the ideal number of respondents for semi-structured interviews, several factors must be considered, such as the complexity of the research, the availability of qualified experts and other contextual limitations. Existing literature suggested a broad range of sample sizes for qualitative research. Creswell and Creswell (2017) indicate that sample sizes can vary from as few as one to as many as thirty, while Creswell (1998) recommended a range of 5 to 25 respondents, which is often sufficient to achieve data saturation. Consequently, this study involved the participation of five respondents from various similar studies within the construction industry (Durdyev et al., 2022; Aziz and Zainon, 2023). Table 2 summarises the background information of the respondents selected to participate in the interview.

Data Collection and Analysis

An interview protocol was developed in accordance with the recommendations provided by the findings of semi-structured interviews (Adeoye-Olatunde and Olenik, 2021) and a comprehensive review of existing literature. The interview was organised into three main sections: introduction, DT barriers and conclusion.

Before the interview, the interview protocol was shared with the respondents to ensure they were well-prepared. A total of five interviews were conducted between June and July 2024 through both online (Zoom) and face-to-face sessions, each lasting an average of 75 minutes. These interviews were recorded and transcribed with the respondents' consent for analysis.

In qualitative research, data analysis follows an iterative process involving exploration, interpretation and coding (Braun and Clarke, 2021). Accordingly, this study employed a hybrid coding approach, combining deductive and inductive methods (Byrne, 2022). Initially, priori codes were established based on the research question and literature. The deductive phase involved coding data into these predefined categories, while the inductive phase allowed for identifying and refining subcodes within the established themes. Data analysis was conducted using MAXQDA (version 24.0.0), a qualitative analysis software that facilitated systematic coding (Kuckartz and Rädiker, 2019). The transcribed interviews were imported into MAXQDA, with each transcript treated as a separate document. Codes were created in MAXQDA and text segments were coded by highlighting relevant sections and assigning the appropriate codes.

Table 2. The background of the respondents

Respondent's ID	Role	Organisation Type	Sector	Years of Experience	Certification	Involvement in DT Projects
R1	Digital Transformation Lead	Education	Public	34	Certified Facility Management Manager (cFMM) (CIDB)	Led multiple DT projects, including BIM integration and IoT deployment
R2	Head of Client Solution	Facilities and property management	Private	20	Project Management Professional (PMP)	Developed and implemented DT strategies
R3	Senior Facilities Manager	Public works department	Public	17	Certified Facility Management Manager (cFMM) (CIDB)	Managed DT rollout in government facilities
R4	Chief Executive Officer	Facilities Management technology developer	Private	22	IFMA member, cFMM (CIDB), Personal Certification in Business Digitisation and Transformation (Lincoln University College)	Spearheaded DT product innovations
R5	FM consultant	Consultancy services	Private	14	IFMA member	Comprehensive DT strategy development

RESULTS AND ANALYSIS

This section presents the findings derived from the analysis of the interview data. Within this section, the barriers encountered in the in-depth interviews were discussed.

Barriers to Digital Transformation in Facilities Management

The investigation into the complexities of DT in the FM sector revealed a spectrum of barriers that had impeded its successful implementation. To systematically analyse these barriers and understand their varying impact on the DT process, the barriers were categorised into five key domains: technological, organisational, people, process and financial barriers (as shown in Table 3), establishing a structured framework for analysis.

Table 3. Barriers to DT in FM

Domains	Constituents
Technological	Compatibility and integration with hardware
	Understanding of technology's role and type of technology
	Data management
Organisational	Lack of digital roadmap/strategy
	Organisational structure and culture
	Lack of leadership support
	Change management
Process	Undefined processes
	Process alignment with digital tools
People	Lack of FM competency
	Lack of ability to adapt to change
Financial	Budget constraints
	Unclear responsibility and financing
	ROI concerns

Technological barriers

Integration with hardware, understanding of technology's role and data management concerns emerged as significant technological barriers to DT. The challenge of compatibility and integration with hardware in FM highlighted the difficulty in seamlessly integrating new technologies with existing systems was unanimously agreed by the respondents to be a significant obstacle

in the DT journey of FM. Their incompatibility can lead to disruptions and inefficiencies that hinder the intended benefits of DT. Respondent R5 alluded to this barrier:

> The main challenge with technology is integrating our systems with hardware. When it comes to software, there aren't many issues anymore, but making sure they seamlessly connect with our physical infrastructure remains a hurdle. Like ensuring maintenance software communicates flawlessly with the IoT sensors/devices in our building is where it gets tricky. (R5)

The strategic integration of technology within FM operations is a central element crucial for enhancing efficiency, cost savings and overall performance and elevating the competitiveness of FM compared to the traditional FM practice. However, a lack of understanding of the role of technology across FM operations posed an obstacle to achieving a seamless DT in the FM sector.

> In our experience, people often mix up a CMMS with a building management systems and even a complaint management system. When people see CMMS, they think it's just for handling complaints. But, a CMMS has more to it, like preventive maintenance scheduling, etc. So, there's this continual mix-up in understanding the roles of these tools. (R1)

In addition, the proliferation of recent and diverse technological systems contributed to the challenge in selecting and understanding the benefits of these technologies. This complexity raised concerns about clients becoming overwhelmed by the multitude of technologies and lacking the expertise to effectively evaluate their investments and potential benefits. This challenged clients as they grappled with the complexity of choices and strived to understand how these advancements aligned with their specific needs and operational goals.

> Not all technologies fit every business. The challenge lies in figuring out what suits a client's unique needs. For instance, a mall might only need the basics, like a CMMS, to log activities, not high-tech solutions like a digital twin, especially for tenants' areas. The focus is on addressing complaints promptly. It's all about tailoring technology to the business needs and this continues to pose a challenge. (R4)

In addition, the analysis revealed that data management in FM primarily centred around overseeing and analysing large data volumes. While efficient data storage solutions can be devised, a critical impediment arises from a lack of human interest or engagement in data processing. Respondent R2

imposed that, “When it comes to processing data, we’re left hanging without any human support, despite having the tools. It’s like having the tools without someone keen to use them for the job”.

The study’s observation reflected a critical aspect of the broader challenge faced by FM in efficiently utilising data for decision-making and operational improvements.

Organisational barriers

Organisational barriers faced by FM during DT were structural and cultural. The respondents highlighted that the efficacy of digital tools in FM was hindered when these tools were not seamlessly integrated into the organisational structure. Whether the organisation follows a hierarchical or flat structure, the critical aspect is how information supplied was utilised within the specific segment of the organisational chart. The challenge intensifies when digital tools, such as technicians, are delegated to roles that may not fully comprehend or utilise their capabilities, rather than being designed for key decision-makers. This structural misalignment between tool functionality and user understanding hindered the effective implementation of digital tools designed to enhance decision-making and operational efficiency. Moreover, the challenge extended to the organisation’s culture, particularly its approach to information. The challenge arose when organisations generated information but lacked a structured approach to effectively harness and apply this data. This deficiency in information utilisation stressed a cultural issue where the organisation failed to foster a proactive culture of information retrieval and application. In addition, the key organisational challenge was concerned with adopting digital tools and creating a culture that actively engages with and pulls valuable information from the DT process.

> If they’re not pulling in this information and just pushing it out, creating a lot of data without using it, that organisation will fail in their DT. The real challenge is when the organisation isn’t structured to pull information. Too many just create data that nobody uses. They’re just in the business of pushing data out, but nobody looks at it. (R3)

Another prominent challenge echoed by the respondents was the absence of a clear roadmap to guide the transformative process in FM. The prevailing reliance on a trial-and-error approach resulted in a concerning pattern of internal investment wastage. According to respondent R2, “We don’t have a clear roadmap and no vision laid out to guide us”.

This succinctly captured the overarching issue of a lack of vision clarity, hindering the sector's ability to chart a well-defined course for DT. Further emphasising the significance of this challenge, respondent R5 stressed the significance of having a digital vision in strategic planning, "When the objectives and vision are clear, it becomes easier for management to map out the roadmaps". This challenge, therefore, illuminated the intricate interplay between vision clarity and strategic planning that posed a formidable obstacle to effective DT in FM.

Furthermore, the study findings indicated that the pervasive struggle to secure leadership support was a formidable barrier hindering DT within FM. There was a persistent issue where managers faced difficulty securing endorsement from top management. This was particularly obvious with the disparity in understanding the potential benefits of such transformative efforts. In particular, the essence of the challenge was in the respondent's assertion that managers often encountered resistance from executives, who might not fully comprehend the positive impacts of DT on FM operations. Moreover, this lack of alignment hindered the ability to secure buy-in from leadership, impeding the initiation and successful execution of DT initiatives. The respondent's frustration with the inability to convey the benefits further underscored the vital role of effective communication and education in fostering the necessary support from organisational leaders.

> Often, the supervisors cannot get the support from the bosses. For instance, we might have innovative initiatives, but if the managing director isn't keen to listen, it becomes an uphill battle. Even if the changes we propose would benefit him and the business, a lack of understanding becomes a barrier. I believe leadership support is a crucial piece for DT and that's what we're often missing. (R2)

In addition to these barriers, change emerged as a crucial factor in the DT journey of FM. The architecture, engineering and construction sector is characterised by a historical resistance to innovative practices and a preference for traditional ways of doing things. Respondents underscored the necessity for FM organisations to depart from traditional approaches and embark on a comprehensive reevaluation of their business structures. Concurrently, the shift extends beyond mere technological adaptation and requires a holistic transformation of work processes and the organisational ethos. Central to this transformation is the intricate challenge of managing the change process. As mentioned by respondent R3, "The organisation challenge is always about the change management, shifting from traditional to embrace a digital paradigm".

A significant aspect of this challenge was the resistance from employees. In general, there were apprehensions about monitoring and negative perceptions surrounding the integration of digital tools. Respondent R1 succinctly captured this sentiment, stating, "People start to create a negative thought, the employee is like, what, I've got to log in and track my time, or questioning the need to log in for work orders or to update maintenance activities". Collectively, these sentiments underscored the significance of effective change management strategies in navigating the complexities of transitioning from the traditional to the digital era.

Process barrier

The core of the process challenge in DT within FM was the stark absence of well-defined workflows and structured processes. "It's all about process challenges. The processes are undefined and the processes are unstable" (R4). Respondent R4 captured a prevailing theme in FM, where a deficiency in essential process elements – such as workflow diagrams – hampered the sector's ability to structure and visualise processes effectively. This also echoed that automation was an ambiguous endeavour without these foundational elements. The respondents compellingly argued that one could not automate what did not exist.

> You have a service but no workflow. Then, you want to automate it. Take, for example, a CMMS. The software isn't a substitute for your maintenance management system. You need a system with visions, missions, philosophies and all your KPIs, timelines and everything that defines your maintenance strategy. The software removes the complexity of volume, not replacing your maintenance management strategy. (R3)

This highlighted a prevalent misconception within the sector, challenging the notion that computerisation alone can replace the need for a well-structured maintenance management system. It further emphasised the critical distinction between automation and the foundational processes that should precede it. As highlighted by R1:

> DT works only if it is in the process. Let's say, for example, you have a work order process; if the work order software is not in the process, then nothing is going to get recorded; nothing is going to get automated. So, our challenge is how to get it into the process.

Echoing this sentiment, R4 concluded, "In the absence of a well-defined, established process, the quality of service in FM is heavily contingent on the personal culture of the facilities manager".

In addition, the study found that compatibility between FM organisational processes and available technology was a major hurdle in DT. Organisations grappled with the significant hurdle that not every technology or system seamlessly adopted existing processes, necessitating extensive and often complex customisation efforts. However, this endeavour faced constraints as specific systems impose limitations on the extent of customisation.

> The challenge is that not every technology aligns with our current processes and there's limited customisation. Some systems require us to adapt to their workflow, which restricts us. If we could navigate more customisation options, that would allow us to tailor our products and services better to meet the unique needs of customers. It's a bit of a problem right now because our way of doing things needs to match the system. (R1)

People barrier

The people barriers associated with DT in FM represented a complex interplay of attitudes, skills and the impact of external factors, such as the COVID-19 pandemic. Initially, the landscape was marked by considerable resistance to change. Individuals, particularly technicians with significant experience, were reluctant to embrace digital processes. However, the dynamics shifted significantly with the onset of the COVID-19 pandemic. As R5 noted, "Post-pandemic, it was quite challenging because people were very reluctant to change the existing processes to what we are implementing now. I believe the pandemic was truly a game-changer, no doubt about it". There is a consensus among the respondents that acceptance of digital technologies is no longer a significant hurdle. R1 further emphasised, "Acceptance isn't much of an issue now. Before COVID-19, there were some challenges, but post-COVID-19, we're not encountering resistance from people anymore".

The profound impact of the COVID-19 pandemic played a pivotal role in reshaping attitudes and diminishing the historical challenge of acceptance among FM individuals. As such, people had to adapt to the new normal, recognising the necessity and benefits of technology in FM.

Despite a growing acceptance, the findings revealed a significant issue in the underutilisation of existing technologies, even though they were widely adopted. This presented a substantial challenge as the full potential of technological systems, particularly building automation systems, remained untapped, posing a hindrance to comprehensive DT. The respondents shed light on potential competency gaps among FM professionals, which contributed to this underutilisation of existing systems, hindering the seamless integration of technology into building management practices.

> Almost every noteworthy building has a building automation systems, but they're often used only to control basic things like parking lot lights. Just because a building lacks BIM, does it mean the FM isn't digitally transformed? You already have these sophisticated systems in place, so why are there complaints from FM? The real issue is how many FM professionals truly understand the capabilities of building automation systems? So, it appears the issue lies not with the tool itself but with the proficiency of FM practitioners. (R5)

This study analysis revealed that individuals within FM organisations grappled with the transformational aspects necessary to effectively implement DT initiatives. The struggle was evident in their ability to navigate and manage the essential changes demanded by the DT paradigm.

> Even with all the efforts put into skill development, employee engagement and talent acquisition, we discovered that the real issue we face is adapting to change. It's challenging for individuals to truly manage the essential changes that are demanded by this transformation. (R3)

The focus shifted from overcoming resistance to effectively promoting technology. While acceptance was no longer a major obstacle, there was an emphasis on devising strategies to encourage and facilitate the optimal use of technology.

Financial barrier

The concept of economic feasibility, emphasising the dilemma faced by facilities managers when dealing with assets that have reached a point of irreparable deterioration, sometimes impeded the full pursuit of DT. The complexity of this challenge was accentuated in the FM sector, particularly for outsourced FM. In this context, the fixed and non-negotiable nature of outsourced contracts placed an additional burden on facilities managers. Even when assets were labelled as "beyond economic repair", they were still expected to be managed and maintained within the constraints of the existing contracts. The consequence of this was reflected in the limitations imposed on FM budgets. The budget threshold, determined by the depreciation value, becomes critical. If this threshold were low, it could lead to a situation where virtually no budget is available for necessary maintenance and upgrades. In addition, one of the noteworthy implications of this financial challenge was its direct impact on technology adoption. The respondents highlighted that technology, a crucial enabler in the FM sector, comes at a cost. However, in the presence of a constrained budget due to assets classified as "beyond economic repair", the affordability of technology was a significant hurdle.

> The financial challenge is simple: beyond economic repair. When the cost of maintenance exceeds the depreciation value, it's better to buy new than to repair. Now, the issue is that these items have been asked to be managed by facilities managers, forcing them to cut maintenance costs below depreciation value. Due to this, FM budgets have got a ceiling tied to depreciation and if that ceiling is low, you have no budget and if you have no budget, technology is not cheap. (R2)

Moreover, the respondents highlighted the impracticality of investing in advanced technologies in the FM sector. The short-term nature of contracts and the long-term nature of technological solutions created a misalignment of incentives. Consequently, facilities managers faced the dilemma of investing in technologies that would outlast their contractual obligations, benefiting the owner more than themselves.

> The facilities manager's stance is straightforward: You are telling me to install IoT? Come on, I'm out of this contract in 2 years, but that IoT will be here for a decade. Do you know how much the supplier of the IoT is going to charge me for those full 10 years, not just the 2 years I'm here? And who gets it? The owner, not me. (R4)

As a result, an inherent challenge emerged in determining responsibility for digital systems. The division of responsibilities between facilities managers and owners complicates the financing aspect. Following this, the lack of clarity on whose budget should fund DT creates a significant obstacle in implementing necessary technological solutions.

> People don't know from which pocket you will take the money to do DT. Whose budget do you use? Do you use the owner's budget who is not using the system? Or do you use the facilities manager's budget who doesn't own the system? Without a clear budget, there's no purchase. (R3)

Another barrier mentioned in the DT literature and applicable to the FM sector was budget constraints. This challenge was characterised by limited available funds, impacting the ability to undertake essential DT initiatives. The respondents noted a common misconception regarding DT. FM organisations often embarked on DT initiatives, believing they could save money. However, this assumption often overlooked the comprehensive nature of costs associated with DT. While budgeting for DT, there was a tendency to focus primarily on software prices, neglecting the expenses related to human resources. This oversight contributed to a substantial budget constraint as

the true extent of the financial requirements was not accurately accounted for. In addition, a noteworthy aspect of the budget constraint challenge was the disparity in understanding between contractors and clients. Being fully involved in system implementation, contractors possessed a more comprehensive grasp of the associated costs. On the contrary, clients might lack a thorough understanding, leading to budgetary challenges.

The challenge of ROI in implementing new technology within FM organisations posed a significant hurdle to the seamless adoption of DT. A central theme in the challenge of ROI was the uncertainty associated with implementing new technologies, as posited by respondent R5, "Implementing new technology like this can be quite challenging at times because we struggle to determine the cost benefits and the return on investment". This lack of clarity was a substantial challenge for FM organisations contemplating the adoption of new technologies. Correspondingly, the respondents further delved into the intricacies of ROI calculation, acknowledging that ROI was not always tangible.

> Indeed, FM organisations are keen on evaluating the ROI, but calculating the ROI can be quite challenging. Sometimes, the ROI is intangible. So, we need to figure out how to shift from intangible to tangible aspects. We must find a way to make it tangible, perhaps by assigning a monetary value to it. That's the most difficult and challenging part. (R1)

Respondent R5 even provided a concrete example of calculating ROI through a cloud-based CMMS, "Before adopting this cloud-based CMMS, you needed a team of 10 people. After implementation, do you still require the same 10, or could you achieve the same with just 6 people?" This example involved evaluating whether the same level of workforce is needed post-implementation, leading to potential savings that can be translated into ROI.

DISCUSSION

This section discusses the barriers to DT in the FM sector, as per the study findings. These identified barriers hindered the successful implementation of DT within the sector and undermined its ability to remain competitive in an increasingly digitised world. Adopting a modified TOE framework revealed that DT in FM faced a range of challenges across organisational, technological, process, people and financial dimensions.

In this study, the key organisational obstacles hindering DT in FM included unsupportive organisational structures, the absence of a clearly defined digital strategy and inadequate top management support. These findings resonate with earlier studies across various sectors that establish the foundational role

of organisational readiness in DT initiatives (Agrawal, Narain and Ullah, 2020; Tijan et al., 2021). In particular, this study echoes Kozak-Holland and Procter (2020), who argued that when digital initiatives lack structural anchoring and strategic direction, transformation efforts are likely to stall. Although digital strategies are crucial for aligning technology adoption with broader organisational objectives, the findings suggested that FM organisations often lack this alignment. This aligns with Zaoui and Souissi (2020), who asserted that without a well-articulated digital roadmap, organisations face difficulties in synchronising their transformation efforts with their core business goals. This misalignment is especially concerning in the FM context, where strategic integration is essential for managing various functions. This includes maintenance operations, asset optimisation and sustainability initiatives. Interestingly, while Wrede, Velamuri and Dauth (2020) emphasised that top management support is crucial to the success of DT initiatives, the current study revealed that the FM sector often lacks this leadership commitment. This aligns with the observations of Kazim (2019), who attributed leadership inertia to a limited awareness of the strategic value of digital technologies. Similarly, Magesa and Jonathan (2022) asserted that in the absence of a clear vision and active support from senior leadership, digital projects may lead to failure. Consequently, this results in a cycle where FM organisations remain ill-equipped to embrace and navigate the complexities of digital innovation.

On the technological front, a widespread lack of understanding about suitable technologies and their alignment with FM goals was revealed. This corresponds with Durdyev et al. (2022), who mentioned that facilities managers often struggle with identifying digital solutions that offer meaningful improvements. Agrawal, Narain and Ullah (2020) further noted that mere technology acquisition does not guarantee successful transformation unless aligned with overarching organisational goals. Compounding this challenge is the issue of technological integration, where new digital systems are often incompatible with legacy systems (Omoruyi, 2020). In FM, where building management systems, IoT devices and computer-aided facility management tools must work in tandem, technological misalignment can stifle expected efficiencies (Anathan, Yusof and Rahman, 2023). Furthermore, Dixit et al. (2019) illustrated this issue by exploring BIM integration in FM. The authors highlighted how a lack of interoperability between BIM-FM technologies can significantly undermine the potential benefits of DT.

In contrast to earlier literature, which often positioned resistance to change as a major barrier to DT (Agrawal, Narain and Ullah, 2020; Cichosz, Wallenburg and Knemeyer, 2020; Marocco and Garofolo, 2021), this study presented a counter-narrative. In the post-COVID-19 era, FM professionals appeared more receptive to DT. This supports the argument of Schilirò (2020) that crises can act as accelerators of change, overriding institutional inertia. In essence, the pandemic created operational urgencies that required immediate digital

interventions such as remote monitoring and virtual coordination, thus fostering an environment conducive to transformation. In other words, this shift suggests a significant cultural evolution within FM, wherein crisis-induced necessity has translated into enduring openness to digital adoption.

However, this newfound receptiveness does not imply complete readiness. The study findings revealed that a significant impediment to DT within the FM sector was the deficiency in digital literacy and individual capabilities in change management. This observation is in concordance with the assertion of Marocco and Garofolo (2021), who highlighted the sector's inadequate preparation for managing digital transitions, especially during the operational phase of facilities. As digital tools grow more complex, the skills gap becomes more pronounced, posing long-term risks to transformation efforts. Tijan et al. (2021) similarly argued that the lack of change capabilities continues to slow digital uptake. Therefore, while the pandemic may have stimulated initial digital adoption, sustaining this momentum requires deliberate capacity building.

The findings also found that the absence of well-defined processes and their alignment with digital tools in FM were part of the key barriers to DT. This barrier is also stressed by Matarneh et al. (2019), who argued that FM processes often lack the standardisation necessary for digital enablement. In line with this, Kumari (2023) emphasised that technology cannot replace well-structured processes. Instead, it serves as an enabler that amplifies existing procedural strengths. In FM, where tasks like preventive maintenance or asset lifecycle tracking require coordination, disorganised processes can lead to poor implementation of digital tools. This insight aligns with the view of Cichosz, Wallenburg and Knemeyer (2020), who suggested that digitisation without process alignment may exacerbate operational inefficiencies rather than resolve them. This includes deploying IoT-based energy monitoring without clear workflows for interpreting and acting on the data, which results in limited impact (Poyyamozhi et al., 2024; Raimi, Ogunbayo and Aigbavboa, 2024). This highlights how digital tool effectiveness is contingent on availability and embeddedness within operational processes.

Another key barrier was the limited financial resources, coupled with pervasive apprehensions surrounding ROI in implementing digital tools within the FM sector. Similar findings have been reported by Raimi, Ogunbayo and Aigbavboa (2024), as well as in Dulguun (2023), who noted that financial constraints are particularly pronounced in sectors with tight budgetary controls like FM. Facilities managers, constrained by tight budgets, often prioritise immediate operational needs, sidelining potential long-term benefits of digital innovations. These financial constraints are further compounded by apprehensions about the uncertain ROI from such investments, as the benefits of digital tools in FM, though significant, can occasionally be intangible or long-term. For

example, while a BIM maintenance system with IoT integration can reduce maintenance costs over time, the upfront investment and implementation costs deter many FM organisations from adopting these technologies, even when their potential benefits are well-documented (Ehab, Mahdi and El-Helloty, 2024). Hisamuddin, Mohammad and Lokman (2023) corroborated that financial limitations and ROI considerations critically shape technology adoption in FM. This reflects a trend where immediate financial constraints and the demand for demonstrable ROI in the short term often eclipse the long-term potential of digital tools.

CONCLUSION

DT has brought about significant changes across various industries, presenting a landscape with opportunities for transformative shifts and innovation. However, in contrast to sectors such as finance, information technology, manufacturing, healthcare and even construction, the FM sector, characterised by its complex operational structure, has historically exhibited a conservative approach to embracing innovation. Consequently, it finds itself trailing behind in the swift adoption of digitalisation and the full utilisation of the transformative potential of digital technologies in its operations.

The motivation for this study stems from the lack of empirical research centred on DT in the FM sector. The current literature does not provide a clear insight into the impediments of DT faced by the FM sector, particularly within the context of developing countries like Malaysia. To bridge this gap, the study adapts the TOE framework to identify and analyse the barriers that significantly impede DT in FM. For this purpose, the authors conducted semi-structured interviews with FM experts in Malaysia. The contribution of this study is two-part. First, the study's findings expand the body of knowledge of DT and digitalisation, particularly in the FM sector of a developing country. Accordingly, the insights of the identified barriers provide researchers with a foundation in the field and may offer a starting point for future research design. Secondly, this study advances the understanding of DT barriers in the sector, providing valuable insights for practitioners to shape more effective DT strategies. Moreover, understanding these challenges in the sector is essential for tackling digitalisation issues and creating an effective DT process.

In consideration of the barriers identified in this study, we recommend that FM organisations prioritise fostering a culture of innovation by investing in change management and upskilling programmes to equip staff with essential digital skills. At the same time, clear digital strategies should be developed to align technology with long-term goals and operational processes, ensuring it enhances efficiency rather than adding complexity. Additionally, partnerships with government and private investors can help address financial constraints

through grants or public-private collaborations, easing concerns about ROI. Notably, by implementing these measures, the FM sector in Malaysia can better leverage DT, improving operational resilience and sustainability.

Despite the insightful contributions of the current study, it is essential to acknowledge its limitations while interpreting the findings. The findings were based on feedback from FM experts in Malaysia, which might reflect specific operational and cultural differences in FM practices. In response, future research could explore barriers to DT in other countries or contexts, especially in developed nations and make comparative analyses. Moreover, to improve the generalisability of the results, future researchers are encouraged to use probability sampling methods when investigating barriers to DT implementation. Finally, future research could delve deeper into identifying the root causes of these barriers, examining any interrelations between them and exploring strategies to overcome them.

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REFERENCES

Adade, D. and De Vries, W.T. (2024). An extended TOE framework for local government technology adoption for citizen participation: Insights for city digital twins for collaborative planning. *Transforming Government: People, Process and Policy*, 19(1): 53–73. https://doi.org/10.1108/TG-01-2024-0025

Adeoye-Olatunde, O.A. and Olenik, N.L. (2021). Research and scholarly methods: Semi-structured interviews. *Journal of the American College of Clinical Pharmacy*, 4(10): 1358–1367. https://doi.org/10.1002/jac5.1441

Adhikari, S. D., Hoffman, S. and Lietke, B. (2019). *Six Emerging Trends in Facilities Management Sourcing*. New York: McKinsey & Company.

Agrawal, P., Narain, R. and Ullah, I. (2020). Analysis of barriers in implementation of digital transformation of supply chain using interpretive structural modelling approach. *Journal of Modelling in Management*, 15(1): 297–317. https://doi.org/10.1108/JM2-03-2019-0066

Ahmad, M. and Siraj, S. (2023). Determinants impacting the assimilation stages of e-commerce in SMEs: A modified TOE framework. *International Journal of Electronic Commerce Studies*, 14(2): 101–126. https://doi.org/10.7903/IJECS.2220

Akinshipe, O., Aigbavboa, C. and Anumba, C. (2022). The future of facility management: A case for digital twin. In A. Maciejko (ed.), *Human Factors in Architecture, Sustainable Urban Planning and Infrastructure*. New York: AHFE International, 118–128. https://doi.org/10.54941/ahfe1002360

Ali, I.M., Mohd Nawi, M.N., Abdul Wahab, S.N., Baharuddin, M.N. and Masnan, A. (2023). Facilities management digitalisation model: A systematic literature review. *International Journal of Academic Research in Business and Social Sciences*, 13(3): 757–776. https://doi.org/10.6007/IJARBSS/V13-I3/16354

Aliu, A.A. and Ariff, N.R.M. (2019). How satisfied are international students in Malaysia's public universities? An empirical study on student accommodation facilities. *e-Academia Journal*, 8(1): 114–124.

Aliu, A.A., Ariff, N.R.M., Said, S.A.A.S., Ametefe, D.S., John, D., Dugeri, T.M. and Isah, M. (2025). Adopting systematic review in conceptual digital maturity modelling: A focus on facilities management sector. *Journal of Advanced Research in Applied Sciences and Engineering Technology*, 52(1): 332–355. https://doi.org/10.37934/ARASET.52.1.332355

Altohami, A.B.A., Haron, N.A., Ales@Alias, A.H. and Law, T.H. (2021). Investigating approaches of integrating BIM, IoT and facility management for renovating existing buildings: A review. *Sustainability*, 13(7): 3930. https://doi.org/10.3390/SU13073930

Amos, D., Au-Yong, C.P. and Musa, Z.N. (2020). Developing key performance indicators for hospital facilities management services: A developing country perspective. *Engineering, Construction and Architectural Management*, 27(9): 2715–2735. https://doi.org/10.1108/ECAM-11-2019-0642

Anathan, J.D., Yusof, L.M. and Rahman, R.A. (2023). Internet of Things (IoT) impact on facility management of office buildings: A qualitative study. *Journal of Engineering, Project and Production Management*, 13(3): 0020. https://doi.org/10.32738/JEPPM-2023-0020

Atkin, B. and Brooks, A. (2021). *Total Facility Management*. 5th Ed. Hoboken, NJ: John Wiley & Sons.

Atta, N. and Talamo, C. (2020a). Digital transformation in facility management (FM). IoT and big data for service innovation. In B. Daniotti, M. Gianinetto and S.D. Torre (eds.), *Digital Transformation of the Design, Construction and Management Processes of the Built Environment*. Cham: Springer International Publishing, 267–278. https://doi.org/10.1007/978-3-030-33570-0_24

_____. (2020b). Facility management services in smart cities: Trends and perspectives. In C. Bevilacqua, F. Calabrò and L.D. Spina (eds.), *NMP 2020. Smart Innovation, Systems and Technologies*. Cham: Springer, 220–230. https://doi.org/10.1007/978-3-030-52869-0_19

Aziz, N.M. and Zainon, N. (2023). Driving factors for lean-BIM implementation in Malaysia's construction industry: Qualitative interview-based study. *Smart and Sustainable Built Environment*, 12(4): 872–891. https://doi.org/10.1108/SASBE-01-2022-0019

Bechina, K. and Arntzen, A.A. (2022). A system of systems approach to smart building management: An AI vision for facility management. In *17th Annual System of Systems Engineering Conference (SOSE)*. Rochester, NY: IEEE, 452–456. https://doi.org/doi:10.1109/SOSE55472.2022.9812696

Benevento, E., Stefanini, A., Aloini, D., Dulmin, R. and Mininno, V. (2023). Beyond digital technologies: Investigating the barriers to supply chain integration of healthcare organizations. *IEEE Transactions on Engineering Management*, 71: 13660–13672. https://doi.org/10.1109/TEM.2023.3280329

Boje, C., Guerriero, A., Kubicki, S. and Rezgui, Y. (2020). Towards a semantic construction digital twin: Directions for future research. *Automation in Construction*, 114: 103179. https://doi.org/10.1016/j.autcon.2020.103179

Braun, V. and Clarke, V. (2021). One size fits all? What counts as quality practice in (reflexive) thematic analysis? *Qualitative Research in Psychology*, 18(3): 328–352. https://doi.org/10.1080/14780887.2020.1769238

Bryan, J.D. and Zuva, T. (2021). A review on TAM and TOE framework progression and how these models integrate. *Advances in Science, Technology and Engineering Systems Journal*, 6(3): 137–145. https://doi.org/10.25046/AJ060316

Byrne, D.A. (2022). A worked example of Braun and Clarke's approach to reflexive thematic analysis. *Quality and Quantity*, 56(3): 1391–1412. https://doi.org/10.1007/S11135-021-01182-Y

Chahid, A., Ahriz, S., Guemmat, K.E. and Mansouri, K. (2025). Digital transformation in higher education obstacle assessment and development of strategies against cybersecurity threats: The case of Moroccan universities. *Engineering, Technology and Applied Science Research*, 15(1): 19809–19815. https://doi.org/10.48084/ETASR.8853

Chomistriana, D., Mulyono, A.T. and Najid. (2024). Predicting adoption behaviour to digital government transformation in construction sector. *Journal of Construction in Developing Countries*, 29(2): 181–205. https://doi.org/10.21315/jcdc-12-23-0177

Cichosz, M., Wallenburg, C.M. and Knemeyer, A.M. (2020). Digital transformation at logistics service providers: Barriers, success factors and leading practices. *International Journal of Logistics Management*, 31(2): 209–238. https://doi.org/10.1108/IJLM-08-2019-0229

Cieslak, V. and Valor, C. (2025). Moving beyond conventional resistance and resistors: An integrative review of employee resistance to digital transformation. *Cogent Business and Management*, 12(1): 2442550. https://doi.org/10.1080/23311975.2024.2442550

Codinhoto, R., Fialho, B.C., Pinti, L. and Fabricio, M.M. (2021). BIM and IoT for facilities management: Understanding key maintenance issues. In J. Underwood and M. Shelbourn (eds.), *Handbook of Research on Driving Transformational Change in the Digital Built Environment*. Hershey: IGI Global, 209–231. https://doi.org/10.4018/978-1-7998-6600-8.ch009

Creswell, J.W. (1998). *Qualitative Inquiry and Research Design: Choosing among Five Traditions*. Thousand Oaks: SAGE Publications, Inc.

Creswell, J.W. and Creswell, J.D. (2017). *Research Design: Qualitative, Quantitative and Mixed Methods Approaches*. 5th Ed. Los Angeles: SAGE Publications, Inc.

Dahanayake, K.C. and Sumanarathna, N. (2022). IoT-BIM-based digital transformation in facilities management: A conceptual model. *Journal of Facilities Management*, 20(3): 437–451. https://doi.org/10.1108/JFM-10-2020-0076

Delgado, J.M.D. and Oyedele, L. (2021). Digital twins for the built environment: Learning from conceptual and process models in manufacturing. *Advanced Engineering Informatics*, 49: 101332. https://doi.org/10.1016/J.AEI.2021.101332

Dixit, M.K., Venkatraj, V., Ostadalimakhmalbaf, M., Pariafsai, F. and Lavy, S. (2019). Integration of facility management and building information modeling (BIM): A review of key issues and challenges. *Facilities*, 37(7–8): 455–483. https://doi.org/10.1108/F-03-2018-0043

Dulguun, E. (2023). Implementation of cutting-edge technologies in facility management: Challenges and opportunities in the digital era. *Journal Dimensie Management and Public Sector*, 4(4): 24–33. https://doi.org/10.48173/JDMPS.V4I4.243

Durdyev, S., Ashour, M., Connelly, S. and Mahdiyar, A. (2022). Barriers to the implementation of building information modelling (BIM) for facility management. *Journal of Building Engineering*, 46: 103736. https://doi.org/10.1016/j.jobe.2021.103736

Ehab, A., Mahdi, M.A. and El-Helloty, A. (2024). BIM maintenance system with IoT integration: Enhancing building performance and facility management. *Civil Engineering Journal*, 10(6): 1953–1973. https://doi.org/10.28991/CEJ-2024-010-06-015

El Ammari, K. and Hammad, A. (2019). Remote interactive collaboration in facilities management using BIM-based mixed reality. *Automation in Construction*, 107: 102940. https://doi.org/10.1016/J.AUTCON.2019.102940

Elyasi, N., Bellini, A. and Klungseth, N.J. (2023). Digital transformation in facility management: An analysis of the challenges and benefits of implementing digital twins in the use phase of a building. *IOP Conference Series: Earth and Environmental Science*, 1176: 012001. https://doi.org/10.1088/1755-1315/1176/1/012001

Gausdal, A.H., Czachorowski, K.V. and Solesvik, M.Z. (2018). Applying blockchain technology: Evidence from Norwegian companies. *Sustainability*, 10(6): 1985. https://doi.org/10.3390/SU10061985

Gerrish, T., Ruikar, K., Cook, M., Johnson, M., Phillip, M. and Lowry, C. (2017). BIM application to building energy performance visualisation and management: Challenges and potential. *Energy and Buildings*, 144: 218–228. https://doi.org/10.1016/J.ENBUILD.2017.03.032

Gkrimpizi, T., Peristeras, V. and Magnisalis, I. (2023). Classification of barriers to digital transformation in higher education institutions: Systematic literature review. *Education Sciences*, 13(7): 746. https://doi.org/10.3390/EDUCSCI13070746

Gong, C. and Ribiere, V. (2021). Developing a unified definition of digital transformation. *Technovation*, 102: 102217. https://doi.org/10.1016/j.technovation.2020.102217

Hakimi, O., Liu, H. and Abudayyeh, O. (2024). Digital twin-enabled smart facility management: A bibliometric review. *Frontiers of Engineering Management*, 11(1): 32–49. https://doi.org/10.1007/S42524-023-0254-4

Hauashdh, A., Jailani, J., Rahman, I.A. and Al-Fadhali, N. (2021). Structural equation model for assessing factors affecting building maintenance success. *Journal of Building Engineering*, 44: 102680. https://doi.org/10.1016/J.JOBE.2021.102680

Heilig, L., Lalla-Ruiz, E. and Voß, S. (2017). Digital transformation in maritime ports: analysis and a game theoretic framework. *Netnomics*, 18: 227–254. https://doi.org/10.1007/S11066-017-9122-X

Hisamuddin, E.F.H., Mohammad, I.S. and Lokman, M.A.A. (2023). Determining why facilities management has been conservative in adopting data analytics. *International Journal of Business and Technology Management*, 5(2): 205–218. https://doi.org/10.55057/ijbtm.2023.5.2.19

Hoang, G.V., Vu, D.K.T., Le, N.H. and Nguyen, T.P. (2020). Benefits and challenges of BIM implementation for facility management in operation and maintenance face of buildings in Vietnam. *IOP Conference Series: Materials Science and Engineering*, 869(2): 022032. https://doi.org/10.1088/1757-899x/869/2/022032

IFMA (International Facility Management Association) (2024a). Navigating the technological landscape for facility management. available at: https://ifma.foleon.com/white-paper/navigating-technological-landscape/ [Accessed on 12 July 2024].

_____. (2024b). AI in facilities management: Unlocking the future. Available at: https://blog.ifma.org/unlocking-the-future-of-facilities-management-with-ai#:~:text=AI's%20ability%20to%20process%20and,trends%20to%20optimize%20space%20utilization/ [Accessed on 6 January 2025].

_____. (2023). Leading digital transformation in the facilities management industry. Available at: https://ifma.foleon.com/white-paper/digital-transformation/ [Accessed on 13 July 2024].

Kane, G.C., Palmer, D., Phillips, A.N., Kiron, D. and Buckley, N. (2018). *Coming of Age Digitally*. MIT Sloan Management Review and Deloitte Insights.

Kazim, F.A.B. (2019). Digital transformation and leadership style: A multiple case study. *ISM Journal of International Business*, 3(1): 24–33.

Khanzode, A.G., Sarma, P.R.S., Mangla, S.K. and Yuan, H. (2021). Modeling the Industry 4.0 adoption for sustainable production in micro, small and medium enterprises. *Journal of Cleaner Production*, 279: 123489. https://doi.org/10.1016/J.JCLEPRO.2020.123489

Kıyıklık, A., Kuşakcı, A.O. and Mbowe, B. (2022). A digital transformation maturity model for the airline industry with a self-assessment tool. *Decision Analytics Journal*, 3: 100055. https://doi.org/10.1016/j.dajour.2022.100055

Konanahalli, A., Marinelli, M. and Oyedele, L. (2022). Drivers and challenges associated with the implementation of big data within UK facilities management sector: An exploratory factor analysis approach. *IEEE Transactions on Engineering Management*, 69(4): 916–929. https://doi.org/10.1109/TEM.2019.2959914

Kozak-Holland, M. and Procter, C. (2020). *Managing Transformation Projects: Tracing Lessons from the Industrial to the Digital Revolution*. 1st Ed. Cham: Palgrave Pivot. https://doi.org/10.1007/978-3-030-33035-4

Kuckartz, U. and Rädiker, S. (2019). *Analyzing Qualitative Data with MAXQDA: Text, Audio and Video*. Cham: Springer International Publishing. https://doi.org/10.1007/978-3-030-15671-8

Kumari, S. (2023). Upskilling/reskilling when implementing value-driven technology. *Journal of Supply Chain Management, Logistics and Procurement*, 6(2): 127–139. https://doi.org/10.69554/BMRO6741

Lammers, T., Tomidei, L. and Trianni, A. (2019). Towards a novel framework of barriers and drivers for digital transformation in industrial supply chains. In D.F. Kocaoglu (ed.), *Portland International Conference on Management of Engineering and Technology (PICMET)*. Portland, OR: IEEE, 1–6. https://doi.org/10.23919/PICMET.2019.8893875

Lee, J.Y., Irisboev, I.O. and Ryu, Y.S. (2021). Literature review on digitalization in facilities management and facilities management performance measurement: Contribution of Industry 4.0 in the global era. *Sustainability*, 13(23): 13432. https://doi.org/10.3390/SU132313432

Leipzig, T.V., Gamp, M., Manz, D., Schöttle, K., Ohlhausen, P., Oosthuizen, G., Palm, D. and Leipzig, K.V. (2017). Initialising customer-orientated digital transformation in enterprises. *Procedia Manufacturing*, 8: 517–524. https://doi.org/10.1016/j.promfg.2017.02.066

Lu, Q., Xie, X., Parlikad, A.K. and Schooling, J.M. (2020). Digital twin-enabled anomaly detection for built asset monitoring in operation and maintenance. *Automation in Construction,* 118: 103277. https://doi.org/10.1016/j.autcon.2020.103277

Magesa, M.M. and Jonathan, J. (2022). Conceptualizing digital leadership characteristics for successful digital transformation: The case of Tanzania. *Information Technology for Development*, 28(4): 777–796. https://doi.org/10.1080/02681102.2021.1991872

Mahmood, F., Khan, A.Z. and Khan, M.B. (2019). Digital organizational transformation issues, challenges and impact: A systematic literature review of a decade. *Abasyn Journal of Social Sciences*, 12(2): 231–249. https://doi.org/10.34091/AJSS.12.2.03

Marmo, R., Nicolella, M., Polverino, F. and Tibaut, A. (2019). A methodology for a performance information model to support facility management. *Sustainability*, 11(24): 7007. https://doi.org/10.3390/su11247007

Marocco, M. and Garofolo, I. (2021). Integrating disruptive technologies with facilities management: A literature review and future research directions. *Automation in Construction*, 131: 103917. https://doi.org/10.1016/j.autcon.2021.103917

Matarneh, S.T., Danso-Amoako, M., Al-Bizri, S., Gaterell, M. and Matarneh, R. (2019). Building information modeling for facilities management: A literature review and future research directions. *Journal of Building Engineering*, 24: 100755. https://doi.org/10.1016/J.JOBE.2019.100755

Mehmood, W., Fareed, M., Mohd-Rashid, R., Ashraf, M.U. and Aman-Ullah, A. (2023). The role of facilities management in fighting COVID-19 outbreak: Evidence from Malaysian public hospitals. *Frontiers in Psychology*, 13: 1045972. https://doi.org/10.3389/FPSYG.2022.1045972

Nadkarni, S. and Prügl, R. (2021). Digital transformation: A review, synthesis and opportunities for future research. *Management Review Quarterly*, 71: 233–341. https://doi.org/10.1007/s11301-020-00185-7

Nguyen, T.H., Le, X.C. and Vu, T.H.L. (2022). An extended technology-organization-environment (TOE) framework for online retailing utilization in digital transformation: Empirical evidence from Vietnam. *Journal of Open Innovation: Technology, Market and Complexity*, 8(4):200. https://doi.org/10.3390/JOITMC8040200

Olanipekun, A.O. and Sutrisna, M. (2021). Facilitating digital transformation in construction: A systematic review of the current state of the art. *Frontiers in Built Environment*, 7: 660758. https://doi.org/10.3389/fbuil.2021.660758

Omoruyi, O. (2020). Logistics technology compatibility issues and integration challenges among SMEs in Vanderbijlpark. *International Journal of Business and Management Studies*, 12(2): 517–531.

Parola, F., Satta, G., Buratti, N. and Vitellaro, F. (2020). Digital technologies and business opportunities for logistics centres in maritime supply chains. *Maritime Policy and Management,* 48(4): 461–477. https://doi.org/10.1080/03088839.2020.1802784

Perno, M., Hvam, L. and Haug, A. (2022). Implementation of digital twins in the process industry: A systematic literature review of enablers and barriers. *Computers in Industry*, 134: 103558. https://doi.org/10.1016/J.COMPIND.2021.103558

Poyyamozhi, M., Murugesan, B., Rajamanickam, N., Shorfuzzaman, M. and Aboelmagd, Y. (2024). IoT: A promising solution to energy management in smart buildings; A systematic review, applications, barriers and future scope. *Buildings*, 14(11): 3446. https://doi.org/10.3390/BUILDINGS14113446

Qatawneh, N. (2024). Building a framework to drive government systems' adoption of cloud computing through IT knowledge. *Discover Sustainability*, 5(1): 282. https://doi.org/10.1007/S43621-024-00427-8

Raimi, O., Ogunbayo, B. and Aigbavboa, C. (2024). A comprehensive review of the benefits of virtual reality application for facilities management in the construction industry. *Engineering Proceedings*, 76(1): 31. https://doi.org/10.3390/ENGPROC2024076031

Raj, A., Dwivedi, G., Sharma, A., Jabbour, A.B.L.D.S. and Rajak, S. (2020). Barriers to the adoption of Industry 4.0 technologies in the manufacturing sector: An inter-country comparative perspective. *International Journal of Production Economics*, 224: 107546. https://doi.org/10.1016/J.IJPE.2019.107546

Raza, Z., Woxenius, J., Vural, C.A. and Lind, M. (2023). Digital transformation of maritime logistics: Exploring trends in the liner shipping segment. *Computers in Industry*, 145: 103811. https://doi.org/10.1016/j.compind.2022.103811

Saarikko, T., Westergren, U.H. and Blomquist, T. (2020). Digital transformation: Five recommendations for the digitally conscious firm. *Business Horizons*, 63(6): 825–839. https://doi.org/10.1016/j.bushor.2020.07.005

Salman, A. and Ahmad, W. (2023). Implementation of augmented reality and mixed reality applications for smart facilities management: A systematic review. *Smart and Sustainable Built Environment*, 14(1): 254–275. https://doi.org/10.1108/SASBE-11-2022-0254

Sampaio, R.P., Costa, A.A. and Flores-Colen, I. (2022). A systematic review of artificial intelligence applied to facility management in the building information modeling context and future research directions. *Buildings*, 12(11): 1939. https://doi.org/10.3390/BUILDINGS12111939

Schilirò, D. (2020). Towards digital globalization and the COVID-19 challenge. *International Journal of Business Management and Economic Research*, 11(2): 1710–1716.

Schumann, C.-A., Baum, J., Forkel, E., Otto, F. and Reuther, K. (2017). Digital transformation and Industry 4.0 as a complex and eclectic change. In *Proceedings of 2017 Future Technologies Conference (FTC)*. Vancouver, Canada: The Science and Information Organization, 645–650.

Sharma, S. and Lenka, U. (2024). How does transformational leadership impact organizational unlearning: Insights from persistence theories. *Journal of Organizational Change Management*, 37(1): 150–172. https://doi.org/10.1108/JOCM-07-2023-0302

Shukla, M. and Shankar, R. (2022). An extended technology-organization-environment framework to investigate smart manufacturing system implementation in small and medium enterprises. *Computers and Industrial Engineering*, 163: 107865. https://doi.org/10.1016/J.CIE.2021.107865

Song, Y. and Li, Y. (2022). Digital twin aided healthcare facility management: A case study of Shanghai Tongji Hospital. In F. Jazizadeh, T. Shealy and M.J. Garvin (eds.), *Construction Research Congress 2022: Computer Applications, Automation and Data Analytics*. Arlington, Virginia: ASCE Press, 1145–1155.

Støre-Valen, M. (2021). FM and clinical employees' involvement in the design of eight Norwegian hospital projects. *Facilities*, 39(11–12): 778–801. https://doi.org/10.1108/F-06-2020-0076

Tang, S., Shelden, D.R., Eastman, C.M., Pishdad-Bozorgi, P. and Gao, X. (2019). A review of building information modeling (BIM) and the internet of things (IoT) devices integration: Present status and future trends. *Automation in Construction*, 101: 127–139. https://doi.org/10.1016/J.AUTCON.2019.01.020

Tijan, E., Jović, M., Aksentijević, S. and Pucihar, A. (2021). Digital transformation in the maritime transport sector. *Technological Forecasting and Social Change*, 170: 120879. https://doi.org/10.1016/J.TECHFORE.2021.120879

Tornatzky, L.G., Fleischer, M. and Chakrabarti A.K. (1990). *The Process of Technological Innovation*. Lexington, MA: Lexington Books.

Turk, Ž., De Soto, B.G., Mantha, B.R.K., Maciel, A. and Georgescu, A. (2022). A systemic framework for addressing cybersecurity in construction. *Automation in Construction*, 133: 103988. https://doi.org/10.1016/J.AUTCON.2021.103988

Verhoef, P.C., Broekhuizen, T., Bart, Y., Bhattacharya, A., Dong, J.Q., Fabian, N. and Haenlein, M. (2021). Digital transformation: A multidisciplinary reflection and research agenda. *Journal of Business Research*, 122: 889–901. https://doi.org/10.1016/j.jbusres.2019.09.022

Vial, G. (2019). Understanding digital transformation: A review and a research agenda. *Journal of Strategic Information Systems*, 28(2): 118–144. https://doi.org/10.1016/j.jsis.2019.01.003

Villa, V., Naticchia, B., Bruno, G., Aliev, K., Piantanida, P. and Antonelli, D. (2021). IoT open-source architecture for the maintenance of building facilities. *Applied Sciences*, 11(12): 5374. https://doi.org/10.3390/APP11125374

Vogelsang, K., Liere-Netheler, K., Packmohr, S. and Hoppe, U. (2019). Barriers to digital transformation in manufacturing: Development of a research agenda. In T.X. Bui (ed.), *Proceedings of the 52nd Hawaii International Conference on System Sciences*. Hawaii: HICSS Conference Office, University of Hawai'i at Mānoa, 4937–4946.

Wijeratne, P.U., Gunarathna, C., Yang, R.J., Wu, P., Hampson, K. and Shemery, A. (2024). BIM enabler for facilities management: A review of 33 cases. *International Journal of Construction Management*, 24(3): 251–260. https://doi.org/10.1080/15623599.2023.2222962

Wrede, M., Velamuri, V.K. and Dauth, T. (2020). Top managers in the digital age: Exploring the role and practices of top managers in firms' digital transformation. *Managerial and Decision Economics*, 41(8): 1549–1567. https://doi.org/10.1002/MDE.3202

Xiang, Y., Jiang, Q., Zhang, Y. and Zhou, W. (2022). Identifying barriers to the digitalization of China's real estate enterprises in operations management with an integrated FTA-DEMATEL-ISM approach. *Buildings*, 13(1): 100. https://doi.org/10.3390/BUILDINGS13010100

Yang, E. and Bayapu, I. (2019). Big data analytics and facilities management: A case study. *Facilities*, 38(3–4): 268–281. https://doi.org/10.1108/F-01-2019-0007

Yaqot, M. and Al-Ramadan, B. (2024). Navigating digital transformation in facilities management: A bibliometric study. In P. Solic, S. Nizetic, J.J.P.C. Rodrigues, D. Lopez-de-Ipina Gonzalez-de-Artaza, T. Perkovic, L. Catarinucci and L. Patrono (eds.), *Proceedings: 9th International Conference on Smart and Sustainable Technologies (SpliTech)*. Bol and Split, Croatia: IEEE. https://doi.org/10.23919/SpliTech61897.2024.10612371

Zaoui, F. and Souissi, N. (2020). Roadmap for digital transformation: A literature review. *Procedia Computer Science*, 175: 621–628. https://doi.org/10.1016/J.PROCS.2020.07.090

Zekić-Sušac, M., Mitrović, S. and Has, A. (2021). Machine learning based system for managing energy efficiency of public sector as an approach towards smart cities. *International Journal of Information Management*, 58: 102074. https://doi.org/10.1016/J.IJINFOMGT.2020.102074

Zhan, H., Hwang, B.-G., Zhu, H. and Ang, S.H.P. (2023). Towards a sustainable built environment industry in Singapore: Drivers, barriers and strategies in the adoption of smart facilities management. *Journal of Cleaner Production*, 425: 138726. https://doi.org/10.1016/J.JCLEPRO.2023.138726

Zhong, Y., Chen, Z., Ye, J. and Zhang, N. (2024). Exploring critical success factors for digital transformation in construction industry-based on TOE framework. *Engineering, Construction and Architectural Management*, 32(6): 4227–4249. https://doi.org/10.1108/ECAM-08-2023-0782