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DRIVERS, CAPABILITIES, AND CHALLENGES FOR ADOPTING DIGITAL TWIN IN FACILITY MANAGEMENT: A PROFOUND QUALITATIVE INVESTIGATION

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Abstract

Digital Twin (DT) adoption in Built Environment (BE) industry especially facility management (FM) is still slow. DT in FM can offer accurate time information for asset management and building maintenance systems and provide a supporting decision-making process. However, the current FM industry still practices the traditional way of building operation and maintenance, which is inefficient and the principal cause of loss of information due to the lack of digitalization processes and making data inaccessible. Compare to other industries that has effectively applied DT, FM still in infancy due to the ambiguous concept. Therefore, this study aims to profoundly investigate the drivers, capabilities, and challenges for adopting DT in FM. An explorative qualitative approach was employed through semi-structured interviews with eighteen FM professionals to achieve the study objectives. The interview data were analysed using the thematic analysis approach. The study findings suggest that legislation, technology, organization, streamlining operations and stakeholder value are the drivers for adopting DT in FM. Furthermore, findings show that the capabilities needed for adopting DT in FM are manpower, infrastructure, knowledge, and budget. Lastly, the challenges for adopting DT in FM are cost, people, and technology. In conclusion, the study findings provide valuable insights and understanding for the FM industry to motivate further and take action to use DT.

Keywords: Digital Twin, Emerging Technology, Facility Management, Operation, and Maintenance

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INTRODUCTION

Building Information Modelling (BIM) is a 3D-digital representation of the physical and functional parameters of the facility, based on the knowledge exchange of information and resources, to form a valid basis for decision-making over its life cycle. (Aripin et al., 2019). In addition, BIM also offers continuous and organized views and representations of the 3D model along with accurate data such as costing (4D) and the construction schedule (5D). The rich underlying data and three-dimensional (3D) models enable a variety of trades to interact and coordinate the information with one another to boost productivity and raise the return on investment (ROI) associated with proactive problem-solving methods and virtual modelling (Shen et al., 2016). Today, BIM could also be modelled up to 6D and 7D, which provide sustainability, facilities management, and asset management (CREAM, 2014).

The concept of Digital Twin (DT) was first proposed in 1991, with the idea that by sharing information and data, a digital equivalent to a physical system could be created. The idea of a DT is built around the role of a virtual copy of a target physical entity that is used to conduct experiments or simulations and predict future behaviours to help decision-makers make up their minds or to help automated decision systems determine appropriate solutions to the expected problems (Salem & Dragomir, 2022). During its space exploration missions in the 1960s, the National Aeronautics and Space Administration (NASA) was the first to use DT as the core idea and means of understanding a physical object. NASA used DT models to control and simulate their spacecraft for accurate mapping (Kit, 2022). In 2010, NASA reintroduced the concept of DT as an integrated Multiphysics, multiscale, probabilistic simulation of an as-built vehicle or system that uses the best available physical model, sensor updates, fleet history, and other technologies to mirror the life of its corresponding flying twin (El Jazzar et al., 2020).

DT can be equipped with sensors, gauges, measuring machines, lasers, vision systems, and white light scanning that can sense the physical asset's real-life experience information. DT can accurately predict potential failures, feed information back to the system, and react in response to stimuli. It also allows the collection of information about a physical asset throughout its life cycle and continuously monitors all project processes (Ozturk, 2021). In contrast, design visualizations, quick design choices creation, automated model reliability analysis, report generation, and asset performance forecasting are all made possible by BIM (Radzi et al., 2023). In other words, DT and BIM can resolve several challenges during construction projects and improve project effectiveness (Radzi et al., 2023). However, there are still misconceptions about the connection between DT and BIM. Practitioners are reluctant to investigate DT if BIM is already present in their building projects due to these misconceptions. While there's growing interest in DT within the BE industry, the concept remains unclear for many professionals and researchers. Compared to established applications in automotive, aerospace, logistics, and oil & gas, DT research and use in BE is in its early stages (AlBalkhy et al., 2024). Thus, this study aims to profoundly investigate the drivers, capabilities, and challenges for adopting DT in facility management (FM). To achieve the research objectives, a qualitative approach was utilized, employing interviews with FM industry players. This study adds to the detailed understanding of the factors, including the drivers, capabilities, and challenges that affect DT adoption in FM. This study benefits FM organizations as the outcomes can help FM organizations choose the best practices for successful DT adoption.

LITERATURE REVIEW

Building Information Modelling, Digital Twin, and Facility Management

A BIM model represents the parts used in the construction process to construct a building. It includes geometry, spatial relationships, geographical information, the number and nature of the building components, cost estimating, project schedule, and material inventory. The life cycle of a building can also be replicated using BIM, beginning with from construction phase and ending with the operation phase (Abdullah et al., 2015). In other words, BIM is a project simulation that consists of 3D models of the project components linked to all the necessary information related to the project planning, design, construction, or operation as portrayed. From the FM context, BIM can be defined as a dynamic document collecting instrument in archives used to accurately manage and regulate building data throughout the life cycle, which owners can use to manage facilities during the FM phase (Samsuddin & Zaini, 2022). The advantages of using BIM for facility operations are transparent. Additionally, BIM data and models can be viewed on different platforms and integrated with various digital devices. However, BIM adoption in FM lags behind that of the design and construction phases. The life cycle of construction projects should be considered when employing BIM, which now primarily extends to the design and construction phases (Liu & Issa, 2013). In addition, BIM FM is known to enhance a facility's operation and the operation of facilities management (Ikediashi et al., 2022). According to Samsuddin and Zaini (2022), facility managers have access to facility data using BIM FM, mainly geometric BIM data, which provides essential information such as equipment position, maintainability, and accessibility. Thus, BIM is set to offer a new level of functionality for the FM of a building as well as the physical assets in it.

Digital Twin in Facility Management

A DT is a digital replica of the physical environment, states, and processes. A DT can be used to evaluate the present status and possibly estimate the future state of a digital replica of the built environment. In contrast, a BIM model comprises as-is and historical data (Stojanovic et al., 2018). DT also combines Artificial Intelligence, Machine Learning, and Big Data Analytics to develop dynamic models that can learn and update the status of the physical counterpart from numerous heterogeneous data sources (Hosamo et al., 2022). Changes in the built environment that affect the operating state of the workplace must be noted and handled for FM practices. Operation and Maintenance (O&M) processes are now documented using duplicate, frequently out-of-date information that is typically only available in paper format (Stojanovic et al., 2018). According to Hosamo et al. (2022), DT promotes improvement in AEC-FM operations by enhancing data management and processing using large-scale data, information, knowledge integration, and synchronization. It accomplishes this by continuously integrating data and information during the life of an asset. The work added that real-time data from the Internet of Things (IoT) sensors and devices is integrated into the physical system to improve adaptive updating and provide information for further machine learning and artificial intelligence integration to coordinate and automate the physical counterpart of the digital model after operational changes. Combining a virtual information model with real-time data could considerably improve decision-making during the lifetime of the building (Hosamo et al., 2022). However, due to the industry's delayed technological growth, complicated manufacturing and procurement procedures, disorganized supply chains, timetable constraints, and financial hardship, adopting DT in FM may take more than a decade (Ozturk, 2021). The primary obstacles facing the sector include digital transformation, technological infrastructure, interoperability, systems integration, security, stakeholder concerns, legal issues, a lack of experts, and many others. The restrictions listed above are comparable to the barriers to BIM adoption in the AEC sector. In other words, addressing the barriers to adopting BIM will facilitate DT adoption in the industry (Ozturk, 2021).

Digital Twin applications in Malaysia

BIM adoption in Malaysia has grown with 49% industry players has started using it but still below government's goals which target 70% adoption rate for public and private projects by 2021 (Omar & Mohd Fateh, 2023). The government of Malaysia in 2014 announced the new toll-free Pan Borneo Highway that stretches 1,060 kilometers. Once completed, the highway shall be the backbone of Borneo transportation that plays a major role in opening economic corridors in the region (Bentley, 2020). The project delivery partner, Lebuhraya Borneo Utara (LBU) initiated the first Malaysia BIM workflows for road and highway project. LBU leverage Bentley's ProjectWise to create an open, connected data environment to support the implementation and integration of BIM, GIS, and reality modelling processes. In addition, LBU also leveraging Bentley's ContextCapture by image captured using unmanned aerial vehicles (UAV) to accurately record the entire 1,060 kilometers asset information (Bentley, 2020). Another infrastructure project, Mass Rapid Transit Corporation (MRT Corp) having identified several challenges in construction management and handover of digital as-built information to operations of its first Sungai Buloh-Kajang line, MRT Corp decided to advance its BIM workflows by adopting digital twins using Bentley solutions such AssetWise and iModels for their Sungai Buloh-Serdang-Putrajaya Line (IES, 2020). By using Bentley's AssetWise, MRT Corp manage its data through a custom classification system specifically the KVMRT Classification System to capture all the relevant information related to assets and equipment, in which used by the operations and maintenance teams throughout the railway operational life. Regarding iModels, MRT Corp able to visualise and locate an asset in the 3D model and to gain better understanding of the connected or related assets and equipment (IES, 2020). In conclusion, digital twin has been applied in Malaysia predominantly in mega Infrastructure projects such as the Pan Borneo Highway and Mass Rapid Transit.

RESEARCH METHODOLOGY

The data collection for this study involves acquiring qualitative data from individual interviews with FM personnel with experience in dealing with DT and FM. The interview questions were designed through literature reviews to address and identify the study aims. The questions have gone several testings to ensure the questions are relevant and easy to understand. In addition, one pilot interview session was conducted to test the interview questions and estimate the interview durations. The qualitative data were then analysed using the thematic analysis method. Data collected for the study presented here is used to profoundly investigate the drivers, capabilities, and challenges of adopting DT in FM. The subsequent subsections describe this study's data collection and analysis approaches.

Data Collection

The interview sessions were conducted with FM professionals with experience in dealing with DT in FM. The main reason for conducting the interview is to understand the actual practice in the industry. Also, the target population can provide the relevant information as needed. Open-ended questions were provided to the participants as it enabled the researcher to follow up by asking pointed questions and also enabling the participants to provide as much in-depth information (Turner, 2010). Three main interview questions were asked: 1) What are the drivers for your organization to use DT for FM? 2) What are the capabilities needed for your organization to use DT for FM? and 3) What are the challenges that your organization faces to use DT for FM?. Question 1 aims to obtain what motivates FM organizations to adopt DT in their organization. Question 2 of the interview aims to obtain the ability needed for FM organizations to adopt DT. Question 3 of the interview instead aims to obtain the challenges that hinder FM organizations from adopting DT. The open-ended questions were used to encourage as much detailed information as desired. The data collection involves eighteen interviewees. Respondents from different FM companies are required to acquire different perspectives on the subject matter. After each interview session, a summary of responses was made and sent to participants for validation. The interview process was conducted from the fourth quarter of 2022 until the first quarter of 2023. The sampling method use in this study is purposive sampling where interviewees were found via the professional networking platform LinkedIn. Job titles, industries, and relevant phrases were utilised as search filters to locate individuals who possessed the desired attributes and experience required to give significant insights to the research objectives. Purposive sampling were used to select appropriate participants that are more likely to give useful information and different people have different views and ideas. (Campbell et al., 2020). Once possible respondents have been identified, personalised connection requests and messages explaining the objective of the study and requesting them to participate will be issued. This method not only allows for the recruitment of a tailored and relevant sample, but it also takes advantage of the convenience and accessibility of online networking platforms to quickly engage potential participants. Furthermore, the researcher obtained new respondents through contacts and networking with previously interviewed respondents. Lastly, data saturations of the interviews were achieved when there is no new significant insight and ideas gathered. Table 1 below shows the respondent profile of the interviewees. Most respondents are FM executives, DT-FM executives, and FM Managers.

Data Analysis

Thematic analysis is used in the data analysis to extract patterns from the interview data, as this method can help interpret qualitative data (Braun & Clarke, 2006). The thematic analysis was conducted based on the six phases described in Braun and Clarke (2006): (1) data familiarization; (2) initial coding; (3) themes coding; (4) themes review; (5) defining themes; and (6) output report. The first phase of the data analysis is to familiarize authors with the data obtained. The authors reviewed, reread, and took notes on the initial ideas after transcribing the interview data. The second phase is generating initial codes. The authors coded the data for potential themes and patterns as many as possible. The authors then reviewed, discussed, and agreed on any additional changes to the coding. The third phase of the data analysis is to search for themes based on the initial codes. The authors regularly examined the codes from the second phase and the original data from the first phase when developing the themes. The fourth phase is to go over the themes. To achieve data saturation, the authors evaluated the subthemes regularly, defined and polished them, tested if the themes worked with the coded extracts and the complete data set, and reviewed data to look for additional themes. The fifth phase is to define the themes. The authors continually went back and forth between the themes, codes, and interview transcription to ensure that the themes were true to the independently coded responses. The final phase, the sixth phase, is to report the output of the analysis.

Table 1. Respondent profile

Respondent	Position	Background	Years of Experience
R1	FM Project Manager	Contractor	3 years
R2	Chief Executive Officer	Consultant	20 years
R3	Operational Executive	Contractor	13 years
R4	Technical Manager	Contractor	20 years
R5	FM Manager	Building owner	13 years
R6	FM Manager	Consultant	11 years
R7	Architect	Consultant	2 years
R8	Managing Director	Consultant	23 years
R9	Consultant Engineer	Consultant	4 years
R10	Verifier	Contractor	11 years
R11	FM Manager	Building owner	9 years
R12	Assistant Manager	Building owner	13 years
R13	BIM FM Executive	Contractor	5 years
R14	Assistant Verifier	Contractor	10 years
R15	FM Manager	Contractor	14 years
R16	BIM FM Executive	Contractor	11 years
R17	BIM FM Executive	Contractor	4 years
R18	Manager	Building owner	8 years

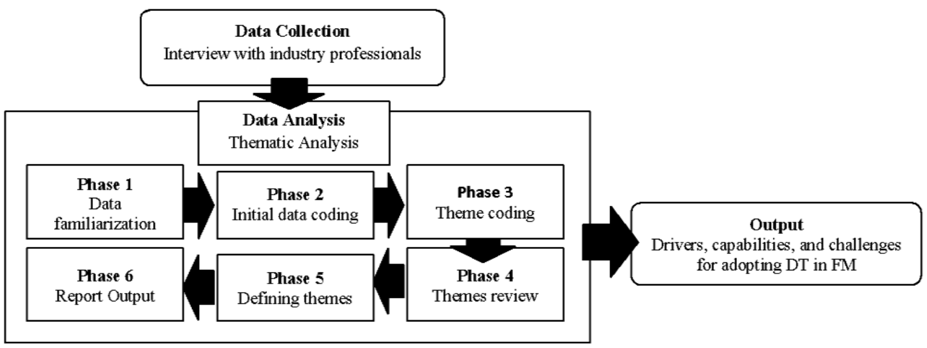

Figure 1. Overview of the research methodology (A R Radzi et al., 2020)

RESULTS AND DISCUSSION

Figure 2 shows the themes of the drivers, capabilities, and challenges for adopting DT in FM. This study has discovered twelve themes with thirty-six subthemes in total (subthemes are shown in subsequent figures). Five themes were identified under drivers: streamlining operational efficiency, legislation, technology, stakeholder value, and organization efficiency. In addition, four themes were identified for capabilities which are manpower, infrastructure, knowledge, and budget. Lastly, three themes that were identified under the challenges are cost, technology, and people. The details of each element are discussed in the subsequent subsections.

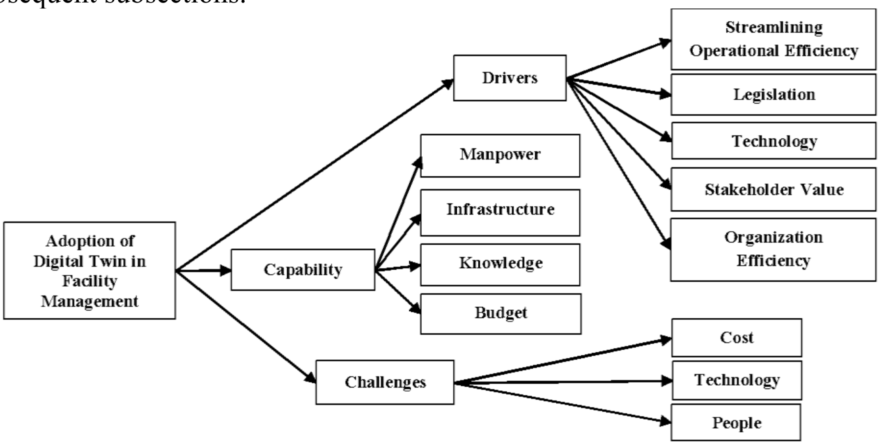

Figure 2. Overview of drives, capabilities, and challenges for adopting DT in FM

Drivers for Adopting Digital Twin in Facility Management

Figure 3 summarizes the themes and subthemes for the drivers for adopting DT in FM. Twelve subthemes were identified, then grouped into five themes: streamlining operational efficiency, legislation, technology, stakeholder value, and organization efficiency. The details of themes and subthemes are discussed in the subsequent subsections.

Streamlining operational efficiency

According to the interview results, one of the themes that drive an organization to adopt DT is the streamlining of operational efficiency. Streamlining operational efficiency is a paramount goal for organizations, enhancing productivity and maximizing resources. Two subthemes, ease of maintenance procedures and ease of processes, stand out as essential contributors to this overarching topic. DT can aid FM organizations in minimizing downtime and disruptions by using proactive maintenance techniques, such as routine inspections and preventative actions. The ease of procedures subtheme also strongly emphasizes streamlining and automating workflows, getting rid of pointless steps, and minimizing manual errors. By adopting DT, FM organizations can be more organized and reduce mistakes.

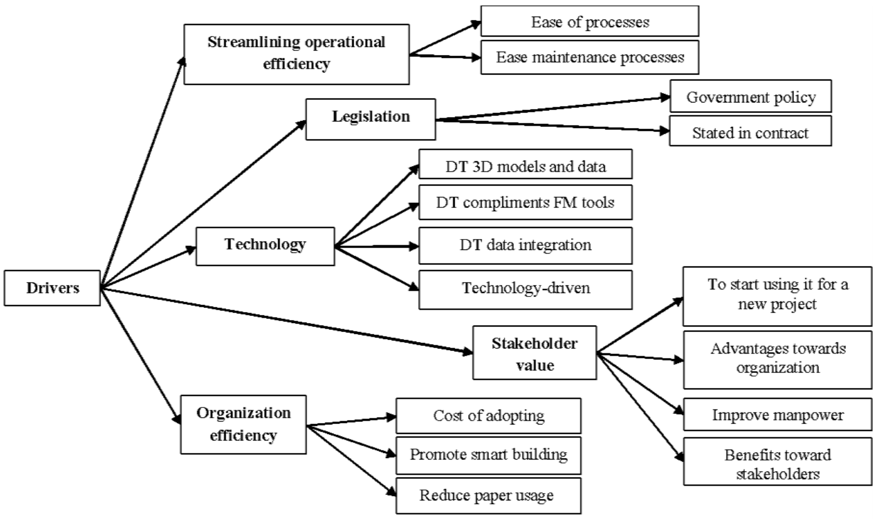

Figure 3. Overview of drivers for adopting DT in FM

Legislation

When examining the theme of legislation, two significant subthemes emerge: "stated in the contract" and "government policy." The subtheme of "stated in the contract" emphasizes the importance of legislative provisions explicitly outlined within contractual agreements. From the interviews, DT was used as the building owner mandated it and stated in the contract to use DT. In addition, it is one of the government policies for public projects that cost more than MYR100 million to use DT. Government policies influenced by legislation also aim to address emerging challenges, adapt to changing societal needs, and promote the overall well-being of the nation.

Technology

When it comes to FM, technology encompasses many subthemes that are rapidly altering the industry. The integration of DT, which enhances existing FM tools and software, is crucial. DT can improve FM processes by utilizing the capabilities of digital models and data, resulting in more effective operations and maintenance. The management of the built environment, accurate data, and visual representation of physical structure are all made possible by using DT-FM 3D model data. Additionally, DT in FM offers seamless data integration, facilitating information transmission across different systems and stakeholders, leading to increased cooperation and decision-making. Lastly, the overall evolution of technology within FM is driven by the constant advancements in software, sensors, and automation, making facilities more intelligent and responsive to the changing needs of occupants and owners. Integrating these technological innovations in FM ensures improved efficiency, sustainability, and performance of buildings and infrastructure in the digital age.

Stakeholder value

DTs are transformative technologies that can potentially enhance stakeholder value in different aspects of the construction industry. One of the subthemes is the usage of DT for new projects. By adopting DT at the early stages of project development, stakeholders can benefit from improved visualization, coordination, and communication. It is much easier to adopt DT at an early stage rather than applying it to existing buildings. Another subtheme is the advantages of DT for FM organizations. Using DT allows an opportunity and empowers an organization. Furthermore, DT has the potential to improve manpower usage in the construction industry significantly. These technologies enable stakeholders to streamline workflows, automate repetitive tasks, and enhance productivity. For instance, DT further enhances efficiency by enabling remote monitoring, maintenance, and troubleshooting of assets, reducing the need for physical interventions and on-site manpower. Overall, the adoption of DT provides several benefits to FM sector players. These technologies allow for better project outputs, more effective FM, more efficient workforce usage, and, ultimately, more stakeholder value.

Organization efficiency

DT is critical in improving organizational efficiency in the FM industry. Although the early costs of adopting DT can be substantial, the long-term advantages surpass the initial costs. DT promotes smart building practices by merging virtual models with real-time data, resulting in a longer life cycle for buildings. Furthermore, the use of DT saves paper consumption dramatically because these technologies enable the digitization of architectural drawings, project documentation, and collaboration processes. This not only speeds up operations but also adds to more sustainable practices by reducing paper waste and fostering a greener atmosphere.

Summary

To summarize the findings for drivers for adopting DT in FM, the theme streamlining operational efficiency shows that DT helps drive FM organizations in minimizing downtime and errors through proactive maintenance and automation. Next, legislation also drives FM organizations to fulfil contractual obligations and comply with government policies that promote efficient building management through DT. In addition, the theme technology allows DT to integrate with FM tools and software by providing 3D modelling, seamless data, and to improve decision-making. Other than that, the theme stakeholder value shows that stakeholder can benefit from DT by improved the communication and workforce efficiency. Lastly, the theme organization efficiency can drive organization to promotes smart building practices, extends building lifespans, and reduces paper consumption for a more sustainable operation through DT. A similar study was done by Ghansah (2024) through his systematic literature reviews shows similar results where the application of DT in FM allows efficient operation and service monitoring of a building.

Capabilities Needed for Adopting Digital Twin in Facility Management
Figure 4 shows the themes and subthemes for the capabilities for adopting DT in FM. Ten subthemes were identified, which were then grouped into four themes which are manpower, infrastructure, knowledge, and budget. The details of themes and subthemes are discussed in the subsequent subsections.

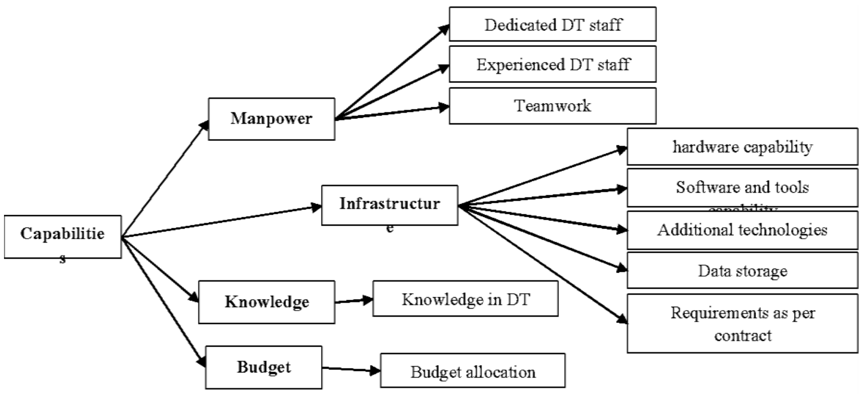

Figure 4. Overview of the capabilities for adopting DT in FM

Manpower
One of the capabilities needed for adopting DT is manpower capability. One critical component is the allocation of dedicated DT personnel. These specialized professionals may be able to handle and operate DT models and data entry successfully. Furthermore, competent individuals proficient in using DT tools are critical in realizing the full potential of these technologies. They must be well-versed, capable of reading 2D and 3D drawings, and multidisciplinary. Furthermore, cooperation is critical in maximizing the capabilities of DT. The potential of these technologies can be fully realized by developing a collaborative

environment in which multiple stakeholders collaborate, exchanging insights and expertise.

Infrastructure

Another critical quality for adopting DT is the infrastructure capability. To begin with, hardware capabilities are critical in enabling the application of DT. To render sophisticated 3D models, cutting-edge gear and computers are required. Furthermore, software and tool capabilities are required for successful DT adoption. For smooth data integration, DT platforms provide intuitive interfaces and a stable internet connection. Furthermore, the incorporation of modern sensors, IoT devices, and artificial intelligence (AI) improves the usage of DT. In terms of data storage, cloud-based storage ensures that DT data are ready to use, and that the data can be handled.

Knowledge

Knowledge of DT is one of the capabilities needed for FM organizations to use these technologies. Such knowledge in DT is understanding standard technical terms and the basic knowledge to handle DT. FM personnel need to be experts in using 3D software and upskill and reskill themselves.

Budget

Finally, FM organizations with financial resources can take advantage of DT advantages by setting aside adequate funds for their adoption and understanding the long-term benefits of these technologies. Additionally, FM organizations can ensure that enough resources, including hardware, software, and qualified employees, are devoted to its deployment. Furthermore, a special allocation for experts and consultants with expertise in DT for engaging skilled professionals to ensure the successful integration of these technologies. Organizations can use the capabilities of DT to optimize financial resources, generate cost reductions, and maximize overall value by carefully allocating funds and taking the ROI into account.

Summary

To conclude, four capabilities for adopting DT in FM were identified. The theme manpower shows that dedicated personnel, skilled users, and collaborative environment are needed for a FM organization. The theme infrastructure shows that FM organizations need the capabilities to have relevant hardware, software, sensors, and cloud storage. In addition, FM organizations must have the knowledge to understanding DT, 3D software expertise, and continuous learning. Lastly, FM organizations must be capable of having budget for DT such as the financial resources for DT adoption, manpower, and consultants, with a focus on

ROI. According to Ghansah (2024) in his study, knowledge building constitutes the ability to gain new knowledge by using DT and, upskilling and reskilling current manpower can generate better understanding of DT.

Challenges for Adopting Digital Twin in Facility Management

Figure 5 shows the themes and subthemes for the challenges of adopting DT in FM. Eleven subthemes were identified, which were then grouped into three themes cost, technology, and people. The details of themes and subthemes are discussed in the subsequent subsections.

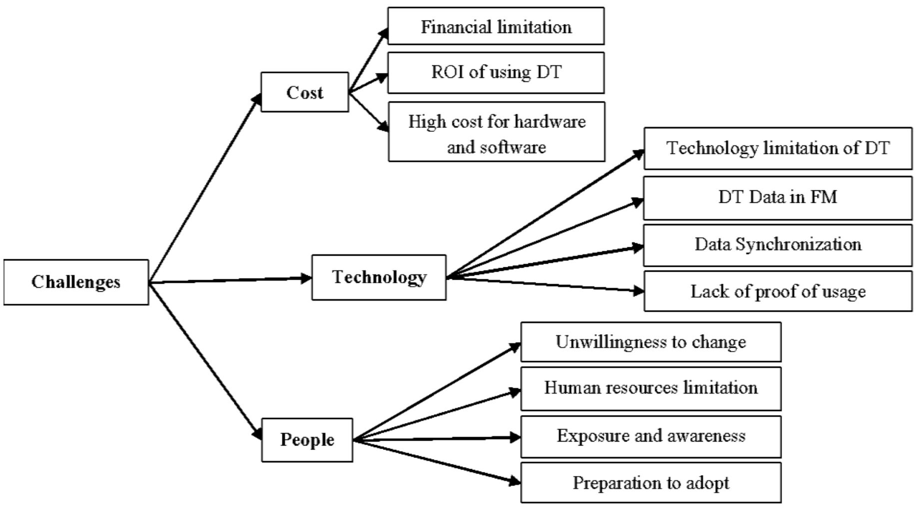

Figure 5. Overview of the challenges for adopting DT in FM

Cost

According to the interview findings, some significant challenges prevent DT adoption in FM. Financial constraints hamper widespread adoption, the requirement to demonstrate an ROI for DT, and the high costs of software and hardware acquisition. Lack of funding may prevent businesses, especially small and medium-sized ones (SMEs), from adopting DT.

Technology

Technology is also one of the challenges to adopting DT in FM that needs to be addressed. Firstly, technology limitations pose a significant hurdle. This can be due to a lack of proper infrastructure, such as hardware and software, to run DT. Secondly, ensuring effective integration between DT data for FM purposes can be challenging. The synchronization of data of DT also takes time and requires careful attention to prevent data clashing. Thirdly, the lack of proven usage and practical adoption examples of DT can impede adoption. Organizations may hesitate to invest in DT without concrete evidence of its benefits, hindering widespread adoption.

People

The findings also show that people or human factor is one of the themes for the challenges in adopting DT in FM. Unwillingness to change and resistance to adopting new technologies can hinder the widespread adoption of DT. Individuals such as top management within organizations may be hesitant to embrace these transformative technologies. Additionally, there may be a limitation in the availability of skilled human resources with the necessary expertise to adopt DT systems effectively. Upskilling existing employees or recruiting new talent can help address this challenge. Furthermore, the exposure and awareness of DT benefits and capabilities among key stakeholders may be limited. This can be due to the wrong perception of using DT from the FM industry perspective. Lastly, adequate preparation is crucial for successful adoption. Organizations need to assess their readiness to adopt DT, which takes time to adopt new trends, evaluate existing workflows, and prepare adequate infrastructure.

Summary

In conclusion, five themes were identified for challenges faced by FM organizations for adopting DT. The first challenge was cost where it involved financial constraints, difficulty demonstrating ROI, and high software and hardware costs. Next, technology limitations such as infrastructure, data integration challenges, and the lack of proven use cases. The last challenge faced by FM organizations are people management where there is resistance to change, limited skilled workforce, low awareness on DT, and inadequate preparation. These findings are in line with Ghansah (2024) where challenges associated with DT in FM is the social and technical issues. Ghansah (2024) added that social issues such as high cost of involving technologies and technical issues being that lack of a systematic and comprehensive reference model.

STUDY IMPLICATION

This study contributes to understanding the drivers, capabilities, and challenges of adopting DT in FM organizations. From the findings, future research can develop frameworks and strategies to increase the awareness and adoption of DT in FM. Other than that, future research should seek a larger sample size that can represent the local industry to acquire more generalizable findings. In addition, the study findings could help policymakers and FM organizations to work together and develop suitable plans and blueprints for adopting DT. The drivers of adopting DT in FM organizations can be a pathway that helps other players in the architecture, engineering, construction, and operation (AECO) industry to adopt DT in their organizations. Furthermore, the capabilities for DT adoption can help AECO industry players to measure themselves in preparedness to adopt DT. In the context of managerial level implication, the study findings could help FM managers on increasing awareness among their teams about the benefits and potential of using DT in FM. This could involve organizing training sessions or workshops to educate FM personnels about the benefits of adopting DT. Besides, FM managers can establish awareness campaigns within their organisations to convey the benefits and possibilities of DT adoption. This could include providing case studies, success stories, and tangible instances of how DT has positively impacted other FM organisations. On top of that, collaboration among other players in AECO industry to share insights and experiences related to DT adoption can be good collaborative approach by FM managers. Along with that FM managers as well as FM organizations should work actively with policymakers to build plans and blueprints that support DT adoption. Policymakers and FM experts can collaborate to establish a favourable environment for DT adoption through supportive rules, incentives, and resource allocation. Lastly, the challenges of adopting DT can prepare FM organizations and other industry practitioners to be aware of the potential challenges. Accordingly, the findings will enhance the awareness of DT and its benefits of adopting it, such as enabling AECO organizations to assess and monitor infrastructure performance in real-time and operate efficiently. In conclusion, this study provides researchers and industry practitioners with a set of variables that influence the adoption of DT in FM.

LIMITATION

The limitations of the findings are as follows. Firstly, this study investigated the drivers, capabilities, and challenges of adopting DT from FM organization perspective. Secondly, the interview sessions were conducted via online virtual platform. Thirdly, this study focused on respondents from a single country, specifically from FM organisations background. Lastly, full usage of DT in FM is still lacking globally. Despite these limitations, the study objectives are still achieved successfully. Therefore, the study findings could be adopted and modified to be use by other nations. Future research can also further access the variables via quantitative approaches.

CONCLUSION

In conclusion, this study sheds light on the growing interest in DT and FM. By exploring the relationship between DT and FM, this study highlights the potential benefits for the FM industry. Therefore, this study aimed to profoundly investigate the drivers, capabilities, and challenges of adopting DT in FM. The study involved conducting interviews with 18 industry professionals. The findings indicate that the drivers for adopting DT in FM encompass several crucial factors, including streamlining operational efficiency, compliance with legislation, leveraging technological advancements, enhancing stakeholder value, and improving organizational efficiency. In contrast, the capabilities needed to adopt DT in FM revolve around having adequate manpower, appropriate infrastructure, knowledge of DT, and sufficient budgetary resources. Additionally, the study identified the challenges faced when adopting DT in FM, which include the cost of adopting DT, technological constraints, and the human factor. These challenges must be carefully addressed and overcome to ensure the successful integration of DT in FM practices. Therefore, the aims of this study to investigate the drives, capabilities, and challenges for adopting DT in FM have been achieved. Overall, this study adds to the current FM body of knowledge by offering unique insights into the drivers, capabilities, and challenges connected with DT adoption. The study findings can be a significant resource for FM practitioners looking to leverage DT. By efficiently integrating DT, the FM industry may capitalize on its benefits and alter its operations more efficiently and sustainably.

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