Journal of Design and Built Environment
E-ISSN: 2232-1500 |Print ISSN: 1823-4208
https://ejournal.um.edu.my/index.php/jdbe
Special Issue V, 2025, 112-125

Barriers in The Integration of Digital Twins (DTs) And Building Information Modelling (BIM) For Predictive Maintenance in Facility Management

M.F.M Kamal[1*], I. Yin[2], A.A. S. Muthuveeran[3], H.M. Affandi[4], N.M. Nasir[5]

[1]Department of Engineering Technology, Faculty of Technical and Vocational, Sultan Idris Education University, 35900 Tanjong Malim, Perak, Malaysia.
[2]Urban Planning Cluster, School of Housing, Building and Planning, Universiti Sains Malaysia, 11800 USM, Pulau Pinang Malaysia.
[3]Department of Landscape Architecture, Faculty of Design and Architecture, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia.
[4]Department of Engineering Education, Faculty of Engineering and Built Environment, National University of Malaysia, 43600 Bangi, Selangor, Malaysia.
[5]Department of Quantity Surveying, School of Architecture, Planning and Surveying, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia.

*Corresponding author: firdaus.mk@ftv.upsi.edu.my

Article info:

Submission date: 11th September 2024
Acceptance date: 12th December 2024

Keywords:

Digital Twins, Building Information Modelling, Predictive Maintenance, Facility Management.

ABSTRACT

The construction sector is progressively employing sophisticated technologies to optimize operational efficiency and the durability of constructed environments. Digital Twins (DTs) generate exact digital duplicates of tangible objects, whereas Building Information Modelling (BIM) offers encompassing digital depictions of a building's physical and functional attributes. Integrating these technologies enables a proactive approach to maintenance and management through the constant monitoring, data analysis, and predictive insights they allow. This study examines the obstacles to using BIM and DTs to help predictive maintenance in facility management. A qualitative method utilizing focus group discussions was conducted to examine the use of DTs and BIM in this field. Using purposive sampling, 12 industry practitioners with experience utilizing and applying BIM and digital twins were chosen. The results have identified the problems and obstacles in integrating BIM and digital twins, offering industry practitioners insightful information and opening the door for more developments in construction technology.

1.0 INTRODUCTION

In the context of contemporary building and facility management, the integration of DTs and BIM presents a significant opportunity that could fundamentally reshape the industry. DTs, which are sophisticated virtual replicas of physical assets, allow for real-time monitoring and predictive analysis, offering unprecedented insight into the performance and condition of buildings and infrastructure. Meanwhile, BIM, which involves the creation of detailed digital representations of physical spaces, enables better planning, design, and management of construction projects from inception through to completion and beyond.

Together, these ground-breaking technologies have the potential to revolutionize maintenance procedures, making them more proactive and data-driven. By leveraging the real-time data provided by DTs, alongside the comprehensive information contained within BIM models, facility managers and engineers can anticipate issues before they arise, optimize resource allocation, and extend the lifecycle of building assets. This integration promises to enhance operational efficiency, reduce downtime, and lower maintenance costs, thereby significantly improving the sustainability and profitability of construction projects.

Moreover, the adoption of DTs and BIM is set to usher in a new era of optimism and progress within the construction industry. These technologies not only offer a pathway to smarter, more efficient building management but also pave the way for innovations in areas such as automated maintenance, remote monitoring, and even AI-driven decision-making. As the industry continues to embrace digital transformation, the synergy between DTs and BIM stands out as a beacon of what the future holds—a future where buildings are not just constructed and maintained but are also continuously optimized through the power of digital innovation.

Despite significant technological advancements, the construction industry still grapples with substantial obstacles in the realm of predictive maintenance. The reliance on reactive maintenance methods often leads to increased periods of inactivity, higher maintenance costs, and reduced operational effectiveness. Moreover, the complexity of managing building assets and systems further complicates the task of optimizing maintenance schedules, predicting equipment malfunctions, and ensuring sustainable building practices.

The primary goal of this study is to delve into the challenges that hinder the seamless integration of DTs with BIM in the construction industry. This goal is crucial and should engage and pique the interest of all industry practitioners. This research is highly significant for the construction industry as it provides valuable insights into the preparations for implementing Digital Twins and BIM to revolutionize predictive maintenance and facility management methods. By employing these technologies, organizations may actively monitor building assets, forecast maintenance requirements, and optimize maintenance timetables, resulting in greater operational efficiency, minimized downtime, and improved building performance. This significance should inform and raise awareness among all industry practitioners.

2.0 LITERATURE REVIEW

2.1. Digital Twins (DTs) in Construction

The concept of DTs has its origins in the early 2000s when it was first formally defined by Michael Grieves in 2002 as a virtual instance of a physical asset capable of continuously mirroring the physical world. This technology was initially developed to improve manufacturing processes, but it has since expanded into various fields, including healthcare, smart cities, and aerospace. Over time, DTs have evolved from simple simulations to sophisticated, real-time digital replicas that can predict, optimize, and control the performance of physical systems throughout their lifecycle (Ferko et al., 2022).

Digital twins in construction are virtual reproductions of actual assets, processes, or systems in the built environment. This notion is gaining pace in the industry (Mao et al., 2022). These DTs are sophisticated models that integrate real-time data from sensors to offer precise simulations and analytics (Khajavi et al., 2019). Digital Twin Construction (DTC) is the implementation of information and monitoring technologies in a closed-loop planning and control system for construction management (Yeung et al., 2022). This methodology facilitates a construction management strategy focusing on data and improving decision-making by integrating many data sources (Abou-Ibrahim et al., 2022).

DTs in construction provide proactive and real-time insights into projects, enabling more effective monitoring and control of processes (Schlenger et al., 2022). Through the utilization of DTs, construction organizations may effectively tackle long-standing problems in the architecture, engineering, and construction

(AEC) industry, resulting in enhanced efficiency and productivity (Liu, 2024). The comprehensive methodology of DTC enables the smooth incorporation of DTs into construction management processes, enhancing the workflow's efficiency and effectiveness (Dai, 2024).

In real life, the application of DTs technology has proven effective in monitoring stress levels during the tensioning of pre-stressed steel structures in construction processes (Yu, 2024). This application demonstrates the utilization of DTs to improve the intelligent surveillance of construction operations, guaranteeing structures' structural soundness and safety (Yu, 2024). Moreover, the suggestion has been made to enhance the digitization of civil engineering and raise the standard of intelligent construction practices by including digital twins with Building Information Modelling (BIM) and Cyber-Physical Systems (CPS) (Ryzhakova et al., 2022). This study emphasizes the potential of combining Digital Twins with BIM and CPS to significantly enhance the digitization and intelligence of construction practices, thereby setting new standards in civil engineering.

The inclusion of CPS allows for real-time monitoring and control, making it possible to track the performance of the infrastructure and respond to issues as they arise. By combining Digital Twins with BIM and CPS, stakeholders can access a wealth of real-time data that supports informed decision-making. This could involve analyzing various "what-if" scenarios to optimize construction processes, improve safety, reduce costs, and ensure the timely completion of projects. DTs can be used to simulate the behavior of building systems over time, predicting when maintenance will be needed and preventing potential failures before they occur. The integration with CPS allows these predictions to be based on actual performance data, further increasing the accuracy and reliability of the predictions.

The integration of these technologies can contribute to more sustainable construction practices by optimizing resource use, reducing waste, and enhancing energy efficiency. Digital Twins allow for the simulation of different energy-saving strategies, which can then be implemented in the physical world through CPS. For large-scale or highly complex projects, the integration of DTs, BIM, and CPS provides a robust framework for managing the many variables involved. This could include coordinating the efforts of multiple teams, ensuring that all components of the project are aligned, and tracking progress against the project timeline.

DTs offer advantages beyond project management and can be applied to safety monitoring, such as developing inland canals. Implementing real-time monitoring and response mechanisms to reconstruct digital twins using 3D video fusion can boost safety measures in building activities. Furthermore, the utilization of digital twins in offsite construction has demonstrated the potential to enhance productivity, health and safety regulations, and the overall management of building systems throughout their lifespan.

DTs are increasingly recognized as a transformative technology with a wide range of applications across various industries. The future directions and ongoing research areas in DTs are evolving rapidly, driven by technological advancements and the need for more sophisticated, real-time digital representations of physical systems. There is ongoing research into developing comprehensive digital twins of entire cities to improve urban management and planning. These digital twins can simulate traffic patterns, energy consumption, and environmental impacts, providing city planners with valuable insights for creating more sustainable urban environments (Shahat et al., 2021). However, one of the critical challenges facing digital twins is the lack of standardized development methodologies and interoperability between different systems. Future research is expected to focus on creating universal standards that will allow seamless integration of digital twins across various platforms and industries (Mihai et al., 2022).

2.2. Building Information Modeling (BIM)

Building Information Modelling (BIM) is an advanced process that utilizes 3D models to provide professionals in the architecture, engineering, and construction (AEC) industry with the necessary tools and insights to effectively plan, design, construct, and manage buildings and infrastructure (Khan & Panuwatwanich, 2020). This technology is crucial in the construction industry, especially for making decisions in project management and integrating data during the early stages of planning and design (Rahim et al., 2023). BIM improves the effectiveness of building operations and facility management by delivering a comprehensive facility management model. It provides a holistic approach to managing constructed assets (Qing-sheng et al., 2019).

BIM has a broad impact that goes beyond just the design phase. It also aids in engineering, construction, procurement, and installation activities by allowing AEC personnel to obtain and manage digitally represented building data (Gulbin O. D. 2019). In addition, implementing BIM across the whole construction project process has become increasingly popular. BIM enables effective communication among parties involved and guarantees a synchronized, uniform, and quantifiable building information exchange (Kim & Yu, 2016). BIM-based construction networks consist of individuals from various organizations and disciplines who are geographically scattered. These networks utilize BIM-enabled projects to improve collaboration and the performance of project tasks (Oraee et al., 2019). To enhance understanding of BIM's role at different stages of a project lifecycle, Table 1 has listed how BIM is utilized during various phases.

Table 1. Roles of BIM in Project Lifecycle

Project Lifecycle	Roles
Conceptualization and Design	BIM Initiation: In the early stages, BIM is used for creating 3D models that capture the initial design concepts. These models are essential for visualizing the project and making early design decisions.
	Collaboration: During the design phase, BIM facilitates collaboration between architects, engineers, and other stakeholders, ensuring that all parties are aligned on the project's goals and specifications.
Construction Planning	Scheduling and Cost Estimation: BIM models are used to link design elements with time and cost data, which helps in creating detailed schedules and budget forecasts. This is crucial for planning the sequence of construction activities and managing resources effectively.
	Clash Detection: BIM helps in identifying and resolving potential conflicts (clashes) between different systems (e.g., plumbing, electrical) before construction begins, reducing the risk of costly rework.
Construction Execution	On-site Coordination: BIM models are used on-site to guide construction activities, ensuring that the project is built according to the planned specifications. This includes real-time updates to the model as changes are made.
	Quality Control: BIM supports quality control by providing precise models that can be checked against the physical construction, ensuring that all elements are installed correctly.
Operation and Maintenance	Facility Management: After construction, the BIM model becomes a valuable tool for managing the facility. It can be used to track maintenance schedules, manage space utilization, and plan renovations.
	Asset Management: BIM models can store detailed information about the building's systems and components, making it easier to manage assets throughout the building's lifecycle.
Demolition or Renovation	Deconstruction Planning: BIM can also play a role in planning the demolition or renovation of a building, by providing detailed information on the structure and materials used, which can aid in recycling efforts and minimizing environmental impact.

Scientists and professionals have thoroughly investigated the application of BIM for already constructed structures, focusing on its advantages in cost reduction, time savings, and enhanced communication in facility management (Carbonari et al., 2015). In nations such as Pakistan, Building Information Modelling (BIM) has become crucial for improving project efficiency and effectiveness by promoting collaboration among project participants, including owners, architects, engineers, contractors, subcontractors, and suppliers (Hussain et al., 2022). The Malaysian government has acknowledged the potential of BIM in building projects, emphasizing its use as a digital representation of the physical and functional aspects of facilities connected to a database of project information (Latiffi et al., 2014).

The adoption and application of BIM have become crucial for supporting collaborative and integrated working environments in construction project management as it continues to revolutionize the construction industry worldwide (Ern et al., 2022). The growing use of BIM has led to the emergence of many BIM-related positions, including BIM managers, coordinators, project managers, and lead coordinators. These roles represent the wide range of uses and duties associated with BIM technology (Habib et al., 2022). Pakistan, a developing country, is actively investigating strategies for implementing BIM to improve cost estimation, fabrication drawings, construction sequencing, and conflict detection in construction projects (Akdağ & Maqsood, 2019).

However, in Vietnam, the widespread deployment of Building Information Modelling (BIM) faces hurdles due to legal considerations and aversion to change despite its various benefits. These barriers hinder the country's adoption of BIM (Nguyen & Nguyen, 2021). Nevertheless, the construction industry continues to integrate BIM due to its significant potential to boost decision-making processes, reduce waste, and promote collaboration over the whole lifespan of buildings (Guzman & Ulloa, 2020).

Additionally, BIM software tools have played a crucial role in project planning, guaranteeing superior building quality, cutting-edge design, and effective project management procedures (Vincent et al., 2020). BIM software is evolving to include more advanced features that support the entire lifecycle of construction projects, from design to facility management. Innovations in BIM tools are focusing on improving usability, interoperability, and the integration of real-time data. These advancements allow for more precise modelling, better visualization, and enhanced simulation capabilities. The development of BIM software is moving towards more sophisticated functionalities that support complex analyses, such as structural and thermal performance, which are becoming increasingly integrated into the BIM workflow (Chi et al., 2015).

The future of BIM is closely tied to its integration with emerging technologies such as the Internet of Things (IoT), Artificial Intelligence (AI), and DTs. The convergence of BIM with these technologies is set to transform how data is collected, analyzed, and used in construction projects. For example, IoT devices can provide real-time data that feeds into BIM models, enabling dynamic updates and more accurate predictions. AI can assist in optimizing design processes, automating tasks, and improving decision-making. DTs, which are detailed virtual replicas of physical assets, can be integrated with BIM to create more responsive and adaptive building management systems (Tang et al., 2019).

As projects become more complex, the need for effective collaboration among various stakeholders is increasingly critical. The development of BIM-based collaborative platforms is a key trend that addresses this need. These platforms facilitate seamless communication and coordination between architects, engineers, contractors, and clients. By providing a shared environment for project data, these platforms reduce errors, improve efficiency, and support more integrated project delivery methods. The future of BIM will likely see the proliferation of such platforms, which will support not only collaboration but also the integration of BIM with other enterprise systems, like Enterprise Resource Planning (ERP) and project management tools (Khudhair et al., 2021).

2.3. Integration of BIM and Digital Twins.

The integration of Digital Twins with BIM enables the creation of a comprehensive digital representation of a building or infrastructure, which can be used throughout the lifecycle of the project—from design and construction to operation and maintenance. This integration has been a subject of extensive research, showcasing the potential benefits of combining these technologies for enhanced building control strategies, improved facility management, and innovative applications across various domains. Research by Hauer (2024) focuses on integrating control strategies within the BIM planning process and mapping them into construction and operational models, known as DTs, to streamline and optimize building design and operation. By leveraging the advanced capabilities of DTs, such as real-time monitoring, predictive analytics, and simulation, in conjunction with the detailed modelling and data management features of BIM, construction professionals can optimize building control strategies, enhance operational efficiency, and ensure sustainable building practices. This integration facilitates a seamless transition from the planning and design phase to construction and operation, offering a holistic approach to building lifecycle management.

While study by Bi (2023) delves into the interaction and correction strategy of building completion information for DTs, showcasing the potential for improved data accuracy and decision-making processes. The research highlights the challenges posed by the absence of comprehensive building information in BIM models, emphasizing how this can disrupt the construction stage and complicate later operation and maintenance processes. By focusing on addressing incomplete or inaccurate building information within DTs models, the study by Bi (2023) seeks to improve the quality and reliability of data used for decision-making processes in construction. This approach is expected to lead to more efficient construction processes, streamlined operations, and enhanced maintenance practices in the built environment.

The study by Zakharchenko & Stepanets (2023) on the other hand explores the value of digital twins in intelligent building development, emphasizing the concept as an integration platform for building management systems (BMS) and BIM technologies with IoT solutions. This research highlights the potential of digital twins as a unifying platform that can integrate various technologies to enhance building management and operational efficiency in intelligent buildings. The study underscores the importance of leveraging digital twins as a central hub for integrating diverse technologies in intelligent building development. By serving as an integration platform for BMS, BIM, and IoT solutions, DTs have the potential to optimize building operations, enhance energy efficiency, and improve overall building performance in the context of smart and sustainable environments.

Another study by Zhu & Wu (2021) and Liang (2024) highlights the importance of integrating BIM with Geographic Information System (GIS) for smart city development and the establishment of digital twin systems. This integration enables the visualization, analysis, and management of building models within a GIS environment, offering a comprehensive approach to enhancing building control strategies and optimizing operational efficiency in intelligent buildings. Zhu & Wu (2021) emphasize the significance of leveraging BIM and GIS technologies to provide comprehensive data sources for smart city construction. By integrating these technologies, they aim to compensate for the shortcomings in macro and micro data collection, thereby facilitating more informed decision-making processes and enhancing the overall quality of smart city development. On the other hand, Liang (2024) focuses on the application of smart city construction based on BIM+GIS technology. They highlight how the integration of BIM and GIS can contribute to more effective data integration, quantitative analysis, and the application of technologies in urban management. This integration serves as a foundational element for smart city development, enabling better planning, decision-making, and sustainable urban practices.

The study by Tripathi et al. (2023) explores the applications of a BIM-IoT-GIS integrated digital twin for post-occupancy evaluations, emphasizing the role of the centralized digital twin in data collection and analysis without physical presence in the building. The research demonstrates how the integration of BIM, IoT, and GIS technologies can facilitate remote data collection and analysis for efficient monitoring and assessment of building performance after occupancy. The integration of BIM, IoT, and GIS in DTs for post-occupancy evaluations provides benefits such as real-time data collection, analysis, and visualization of building performance metrics. This approach enhances decision-making processes, optimizes building operations, and supports sustainable practices in building management. By utilizing DTs, researchers and practitioners can gain insights into building performance, identify areas for improvement, and make informed decisions to enhance occupant comfort, energy efficiency, and overall building sustainability.

The West Cambridge Campus project serves as an exemplary case study illustrating the successful integration of BIM and DTs, leading to significant improvements in facility management and predictive maintenance. This project, undertaken by the University of Cambridge, aimed to create a state-of-the-art research and development environment that integrates advanced technologies to enhance operational efficiency and sustainability. The West Cambridge Campus is designed to accommodate various research facilities, laboratories, and office spaces. The integration of BIM and DTs was crucial in managing the complex infrastructure and ensuring efficient operations throughout the building's lifecycle. The project utilized BIM to create detailed 3D models of the buildings, which included information about materials, systems, and spatial relationships. These models served as the foundation for developing DTs that provide real-time monitoring and data analytics capabilities. The DTs technology was implemented to create a dynamic representation of the physical assets within the West Cambridge Campus. This involved integrating IoT sensors and data analytics tools that continuously collect and analyse data from various building systems, such as HVAC, lighting, and security. The Digital Twin enabled facility managers to visualize the current state of the building in real-time, facilitating proactive decision-making and predictive maintenance strategies. Lu et al. (2020).

2.4. BIM and Twin Digitals in Predictive Maintenance.

Implementing predictive maintenance solutions is crucial for optimizing the performance and durability of building infrastructure. Organizations may improve their predictive maintenance processes, increase operational efficiency, minimize downtime, and save costs by employing modern technologies like DTs and BIM. Multiple studies have emphasized the role of DTs and BIM in enhancing predictive maintenance techniques, demonstrating its capacity to transform maintenance practices in the construction sector.

Several case studies have been observed, which has highlighted the application of DTs and BIM application in the practice. Study by Li et al. (2023) creates a predictive maintenance planning framework for facility maintenance management. They achieved this by combining data from BIM, IoT networks, and Facility Management (FM) systems. This framework enhances predictive maintenance plans for building facilities by utilizing data-driven insights and real-time monitoring capabilities offered by DTs and BIM.

Another study conducted by García and Salgado (2021) compares standard preventive maintenance tactics with emerging predictive maintenance methods, including Algorithm Life Optimisation Programming (ALOP) and Digital Behaviour Twin (DBT). These predictive maintenance systems employ DTs to monitor equipment behavior, anticipate probable breakdowns, and optimize maintenance schedules, resulting in enhanced maintenance practices.

Hosamo et al. (2022), on the other hand, examine the use of DTs in identifying faults in buildings, focusing on utilizing IoT technology to improve the effectiveness of facilities management and maintenance. By combining IoT sensors with DTs, organizations can actively identify issues, forecast maintenance requirements, and optimize maintenance schedules, enhancing building performance and decreasing operational expenses.

Teo et al. (2022) propose an efficient maintenance approach that utilizes a data-driven predictive maintenance plan integrating BIM and IoT technologies. By employing DTs and BIM, organizations can enhance building performance, improve operational efficiency, and optimize maintenance activities through real-time data and analysis capabilities.

Integrating Digital Twins and BIM into predictive maintenance techniques substantially benefits the building industry. By employing these technologies, organizations may actively monitor building assets, anticipate maintenance requirements, and optimize maintenance timetables, resulting in greater operational effectiveness, minimized downtime, and improved building performance. Integrating Digital Twins, BIM, and predictive maintenance strategies offers a revolutionary method for facility management, allowing organizations to attain cost reductions, operational superiority, and sustainable building practices.

3.0 METHODOLOGY

This study employed a qualitative research strategy, specifically utilizing the grounded theory method to conduct the research. The choice of a qualitative approach, particularly grounded theory, stems from its unique capacity to generate theory directly from empirical data, making it particularly suitable for exploring complex social phenomena. Grounded theory, as articulated by Barney Glaser and Anselm Strauss, is an inductive methodology that emphasizes the continuous interplay between data collection and analysis, allowing researchers to develop theoretical insights that are firmly rooted in observed realities (Urquhart et al., 2010). This methodological framework is especially advantageous when existing theories are inadequate to explain the nuances of the phenomena under investigation, as it encourages the emergence of new theories that reflect participants' lived experiences (Kristiana et al., 2019).

The focus group discussion strategy has been used as the principal way of collecting data. The primary focus of the discussion has been on the challenges and obstacles related to integrating Digital Twins and BIM in Malaysia. The use of focus groups is particularly suitable for qualitative research approaches, including grounded theory, due to their ability to facilitate in-depth discussions and elicit rich, nuanced data from participants. Focus groups allow researchers to explore participants' views, feelings, and experiences in a dynamic group setting, which can lead to the emergence of themes and insights that might not surface in individual interviews (Morgan, 1997; Hühn et al., 2016). The interactive nature of focus groups encourages participants to build on each other's responses, thus providing a more comprehensive understanding of the topic under investigation (Doody et al., 2013; Doody et al., 2013).

Participants were selected from industry professionals using purposive sampling. Purposive sampling is particularly suitable for this research due to its focus on selecting participants who can provide rich, relevant, and diverse insights into the phenomenon being studied. This method allows researchers to intentionally choose individuals who possess specific characteristics or experiences that are critical to the research question, thereby enhancing the depth and relevance of the data collected Berterö (2012); Urquhart et al., 2010). In grounded theory, where the aim is to develop theories that are closely tied to the participants' lived experiences, purposive sampling facilitates the identification of key informants who can contribute significantly to the understanding of the social processes under investigation (Urquhart et al., 2010; Maz, 2013). The sampling criteria include years of expertise utilizing BIM and other associated technologies, such as Building Management Systems (BMS), Smart IoT Systems, etc. The respondent profile is displayed in Table 2.

Table 2. Respondent Profile

Respondent	Position	Education Background	Nature of Company	Years of Experience
R1	Senior Architect	Architecture	Design Consultant	15
R2	Facility Officer	Mechanical Engineering	Facility Management	8
R3	M&E Engineer	Mechanical Engineering	Design Consultant	10
R4	M&E Engineer	Electrical Engineering	Design Consultant	7
R5	Facility Manager	Facility Management	Facility Management	15
R6	Facility Officer	Real Estate Management	Facility Management	9
R7	Project Manager	Civil Engineering	Developer	10
R8	Architect	Architecture	Design Consultant	8
R9	Facility Officer	Electrical Engineering	Facility Management	7
R10	Civil Engineer	Civil Engineering	Facility Management	9
R11	Facility Manager	Mechanical Engineering	Facility Management	13
R12	Quantity Surveyor	Quantity Surveyor	Developer	7

For the focus group discussion, the researcher has led the discussion session. Focus groups typically involve a moderator who guides the discussion, ensuring that all participants have the opportunity to contribute while keeping the conversation focused on the research objectives (Naeem & Ozuem, 2021; Stalmeijer et al., 2014). The moderator's role is crucial, as they must manage group dynamics and encourage participation from all members, which can be particularly important in settings where some individuals may be less inclined to speak up (Doody et al., 2013; Pyo et al., 2019). The discussions took three hours and are recorded for subsequent analysis

Data analysis from the focus groups involves transcribing the discussions and employing qualitative analysis techniques, such as thematic analysis, to identify patterns and themes within the data (Gundumogula, 2020; Hühn et al., 2016). This process allows researchers to derive meaningful insights that reflect the collective views of the participants, as well as individual experiences that contribute to the overall understanding of the topic (Gilmartin, 2023). Data was analysed using Atlas Ti, and thematic coding was produced from the analysis.

4.0 RESULT AND DISCUSSION

Based on the analysis of the transcribed data, several themes have been identified and important to be highlighted as the major findings. The themes identified are as listed:

i. Availability of specialist
ii. Resource Constraints
iii. Complexity of data and Interoperability challenges
iv. Limited industry standards
v. Cultural Shift and Organizational Change

Implementing and managing integrated BIM and digital twins systems require technical expertise and resources. Organizations may face challenges in acquiring the necessary skills and knowledge to effectively utilize these technologies. From the discussions, most of the respondents agree with this issue. They have said that Implementing BIM and digital twins can be complex and require specialized expertise.

"It's quite a challenge to find employees with knowledge on BIM and BMS systems, since these technologies is not widely used together"

R5: "One have to be really good in different systems for them to integrate the technologies"

R1: "we have already fully utilize our existing staff, and we cannot send them for training, and hiring new staff is not an option for us right now"

R11: The findings highlight a notable difficulty in locating people with the requisite proficiency in BIM and digital twins technologies. Survey participants regularly highlighted the challenge of obtaining highly experienced individuals, underscoring the importance of specialized expertise for the successful implementation of these systems.

Aside from lack of available expertise, organizations also may face resource constraints, such as limited budget, or technology infrastructure, which can impede the effective implementation and utilization of BIM and digital twins for facility management practices. The cost associated with implementing and maintaining integrated BIM and digital twins systems can be a barrier for organizations. Investing in technology infrastructure, software, training, and ongoing support can be resource-intensive.

"With the increase in cost of construction, profit margin has been reduced and we cannot afford to invest in such systems"

R7: "in the long run, the use of this system integration will definitely profitable for us, but due to current challenges and the lack of supporting ecosystem, we cannot invest in something that we need to setup ourselves"

R11: From the findings, it can be said that organisations have financial and infrastructural constraints that impede the implementation of BIM and digital twins. The exorbitant expenses associated with implementation, continuous maintenance, and training pose substantial obstacles.

Integrating BIM and digital twins may face interoperability challenges due to differences in data formats, structures, and levels of detail. Ensuring seamless data exchange between the two technologies can be complex and require standardized protocols. Moreover, managing and updating large volumes of data generated by BIM and digital twins can be a challenge. Maintaining data accuracy, consistency, and relevance over time requires robust data management strategies and systems.

"even with BIM it is quite a challenge, to integrate it with other systems is out of the questions"

R1: "Integrating 2 different systems is quite challenging since the systems is being develop by different people and uses different programming language"

R8: From the findings, most of the respondents agree that the integration of BIM and digital twins presents substantial interoperability challenges as a result of diverse data formats and standards. To guarantee smooth data transfer and uphold data precision, it is necessary to use strong strategies and standardized protocols.

The lack of standardized protocols and guidelines for BIM and digital twins can hinder adoption and interoperability. Organizations may struggle to develop consistent workflows and methodologies for leveraging both technologies effectively. Establishing industry-wide standards and best practices is essential to facilitate seamless integration and collaboration across different stakeholders.

"CIDB should come out with something to guide the industry"

R6: "lack of guideline and proven applied system in the market make it hard for us to adapt the system integration"

R3: From the analysis, the respondents agree that the lack of standardized standards and rules hinders the use of BIM and digital twins. Establishing standardized procedures and methodologies is crucial for promoting efficient integration and collaboration throughout the sector.

Embracing new technologies and workflows, training staff, and fostering a culture of innovation and collaboration are essential for successful adoption. Resistance to change and lack of buy-in from stakeholders can impede implementation.

"although BIM has been around for quite some time, I believe it would take another 10 years for it to be a norm for the construction industry"

R5: "just look at IBS, it has been around since the 80's and yet, not many people opt for the technology"

R6: “Our construction industry is not reactive to changes, it might take time for this technology to be fully accepted and applied”

R11: From the findings, everyone agrees that organisations must undergo a culture shift in order to successfully utilise these technologies. Obstacles of great significance include resistance to change and a need for stakeholder buy-in. Providing instruction to employees and cultivating an environment that encourages new ideas are essential for accepting and implementing new practices.

5.0 DISCUSSIONS AND CONCLUSION

The combination of BIM and DTs offers a favourable prospect for improving facility management methods in the construction sector. Nevertheless, certain obstacles must be overcome in order to successfully embrace and execute this integration. The main challenge in implementing the combination of BIM and DTs is the intricate nature of data management and interoperability. The usage of distinct data formats, structures, and levels of information in BIM models and DTs poses a difficulty in effectively integrating and exchanging data between the two systems. Organisations have a huge technical difficulty in maintaining data consistency, correctness, and compatibility between BIM and DTs.

Another significant obstacle is the need for standardized protocols and rules to integrate BIM and DTs seamlessly. The lack of universally accepted standards and optimal methods obstructs the creation of uniform processes and compatible systems for effectively using BIM and DTs complete capabilities in facility management. Organizations may need help establishing efficient integration strategies and procedures without explicit instructions. The expense is a significant obstacle to implementing BIM and DTs. Implementing and maintaining integrated systems can be demanding regarding resources, necessitating investments in technology infrastructure, software, training, and continuous maintenance. Organizations may need help obtaining the required funding and resources to implement and maintain integrated BIM) and DTs solutions for facility management.

In addition, overseeing and refreshing substantial quantities of data produced by BIM and DTs poses a noteworthy difficulty. Robust data management strategies and processes are necessary to ensure data accuracy, relevance, and consistency throughout time. Without adequate data governance and maintenance policies, organizations may need help guaranteeing the dependability and utility of integrated BIM and DTs data for facility management. And lastly, addressing cultural shift and organizational change is essential for successful adoption of BIM and DTs in facility management practices. By promoting a culture of innovation, collaboration, and openness to change, organizations can overcome resistance, drive technology adoption, and realize the full potential of these transformative technologies in optimizing maintenance strategies and improving operational efficiency.

Ultimately, the incorporation of BIM and DTs presents notable advantages for facility management. However, to achieve successful implementation, it is crucial to tackle obstacles in data management, interoperability, standardization, and cost. Organizations must overcome these obstacles to fully utilize integrated BIM and DTs to optimize maintenance plans, enhance operational efficiency, and promote sustainable building practices in the construction industry.

6.0 REFERENCES

Abou-Ibrahim, H., Lappalainen, E., & Seppänen, O. (2022). Digital Twin of a Design Process: An Exploratory Study. *Proceedings of the 30th Annual Conference of the International Group for Lean Construction (IGLC30)*, 1198–1209. https://doi.org/10.24928/2022/0238

Akdağ, S. and Maqsood, U. (2019). A Roadmap for BIM Adoption and Implementation in Developing Countries: The Pakistan Case. *International Journal of Architectural Research Archnet-Ijar*, 14(1), 112-132. https://doi.org/10.1108/arch-04-2019-0081

Berterö, C. (2012). Grounded Theory Methodology - Has It Become a Movement? *International Journal of Qualitative Studies on Health and Well-Being*, 7(1), 18571. https://doi.org/10.3402/qhw.v7i0.18571

Bi, N. (2023). Research on the Interaction and Correction Strategy of Building Completion Information for Digital Twin. *Computer Journal*, 34(1), 211-223. https://doi.org/10.53106/199115992023023401016

Carbonari, G., Stravoravdis, S., & Gausden, C. (2015). Building Information Model Implementation for Existing Buildings for Facilities Management: A Framework and Two Case Studies. Building Information Modelling (BIM) in Design, Construction and Operations. *WIT Press, Southampton, Boston*. Vol 149, PP 395-406 https://doi.org/10.2495/bim150331

Chen, C., Zhao, Z., Xiao, J., & Tiong, R. (2021). A Conceptual Framework for Estimating Building Embodied Carbon Based On Digital Twin Technology and Life Cycle Assessment. *Sustainability*, 13(24), 13875. https://doi.org/10.3390/su132413875

Chi, H., Wang, X., & Jiao, Y. (2015). BIM-Enabled Structural Design: Impacts and Future Developments in Structural Modelling, Analysis and Optimisation Processes. *Archives of Computational Methods in Engineering.*

Dai, C. (2024). Digital Twin Modeling Method Based On Ifc Standards for Building Construction Processes. *Frontiers in Energy Research*, 12. https://doi.org/10.3389/fenrg.2024.1334192

Dlesk, A., Strogonov, V., Vach, K., & Pollert, J. (2023). Integration of Spatially Oriented Data from Iot to Facility Management and BIM. *The International Archives of the Photogrammetry Remote Sensing and Spatial Information Sciences,* XLVIII-5/W2-2023, 31-36. https://doi.org/10.5194/isprs-archives-xlviii-5-w2-2023-31-2023

Doody, O., Slevin, E., & Taggart, L. (2013). Focus Group Interviews Part 3: Analysis. *British Journal of Nursing*, 22(5), 266-269. https://doi.org/10.12968/bjon.2013.22.5.266

Doody, O., Slevin, E., & Taggart, L. (2013). Preparing for and Conducting Focus Groups in Nursing Research: Part 2. *British Journal of Nursing*, 22(3), 170-173. https://doi.org/10.12968/bjon.2013.22.3.170

Ern, P., Wong, N., Kasim, N., Osman, M., Adnan, S., Natasha, N. & Ali, R. (2022). Acceptance On Building Information Modelling (BIM) Training in Selangor Construction Industry: Current Trend and Impediments. *IOP Conference Series Earth and Environmental Science*, 1022(1), 012012. https://doi.org/10.1088/1755-1315/1022/1/012012

Ferko, E., Bucaioni, A., & Behnam, M. (2022). Architecting Digital Twins. IEEE Access, PP, 1-1. https://doi.org/10.1109/ACCESS.2022.3172964.

García, F. and Salgado, D. (2021). Maintenance Strategies for Industrial Multi-Stage Machines: The Study of a Thermoforming Machine. *Sensors*, 21(20), 6809. https://doi.org/10.3390/s21206809

Gulbin O. D. (2019). Towards A BIM-Based System Integrated to A Virtual Reality Platform. *Tamap Journal of Engineering*, 2018(1). https://doi.org/10.29371/2018.3.62

Guzman, G. and Ulloa, W. (2020). BIM Application in The Operation and Maintenance Management of a Sports Infrastructure. Proc. *28th Annual Conference of the International Group for Lean Construction (IGLC)*, 949-960. https://doi.org/10.24928/2020/0015

Gundumogula, M. (2020). Importance of Focus Groups in Qualitative Research. *The International Journal of Humanities & Social Studies*, 8(11). https://doi.org/10.24940/theijhss/2020/v8/i11/hs2011-082

Habib, U., Nasir, A., Ullah, F., Qayyum, S., & Thaheem, M. (2022). BIM Roles and Responsibilities in Developing Countries: A Dedicated Matrix for Design-Bid-Build Projects. *Buildings*, 12(10), 1752. https://doi.org/10.3390/buildings12101752

Hauer, M. (2024). Integrating Digital Twins with BIM for Enhanced Building Control Strategies: A Systematic Literature Review Focusing On Daylight and Artificial Lighting Systems. *Buildings,* 14(3), 805. https://doi.org/10.3390/buildings14030805

Hühn, D., Huber, J., Ippen, F., Eckart, W., Junne, F., Zipfel, S., & Nikendei, C. (2016). International Medical Students' Expectations and Worries at The Beginning of Their Medical Education: A Qualitative Focus Group Study. *BMC Medical Education*, 16(1). https://doi.org/10.1186/s12909-016-0549-9

Hussain, M., Memon, A., & Bachayo, A. (2022). Building Information Modeling in Construction Industry of Pakistan: Merits, Demerits and Barriers. *Journal of Applied Engineering Sciences*, 12(1), 43-46. https://doi.org/10.2478/jaes-2022-0007

Hosamo, H., Nielsen, H., Alnmr, A., Svennevig, P., & Svidt, K. (2022). A Review of the Digital Twin Technology for Fault Detection in Buildings. *Frontiers in Built Environment,* 8. https://doi.org/10.3389/fbuil.2022.1013196

Khajavi, S., Motlagh, N., Jaribion, A., Werner, L., & Holmström, J. (2019). Digital Twin: Vision, Benefits, Boundaries, And Creation for Buildings. *IEEE Access,* 7, 147406-147419. https://doi.org/10.1109/access.2019.2946515

Khan, S. and Panuwatwanich, K. (2021). Applicability of Building Information Modeling Integrated Augmented Reality in Building Facility Management., 2139-2148. *Proceedings of The 16th East*

Asian-Pacific Conference on Structural Engineering and Construction, 2019. https://doi.org/10.1007/978-981-15-8079-6_196

Khudhair, A., Li, H., Ren, G., & Liu, S. (2021). Towards Future BIM Technology Innovations: A Bibliometric Analysis of the Literature. *Applied Sciences*. 11(3), 1232; https://doi.org/10.3390/app11031232

Kim, K. and Yu, J. (2016). Improvement of Facility Condition Assessment Processes Using BIM Data. *Proceedings of Construction Research Congress 2016: Old and New Construction Technologies Converge in Historic San Juan*. https://doi.org/10.1061/9780784479827.242

Kristiana, I., Suryanto, S., & Hendriani, W. (2019). How to Make Grounded the Preferred Approach to Psychological Research? A Review. *Journal of Educational Health and Community Psychology*, 8(3), 276.

Latiffi, A., Brahim, J., Mohd, S., & Fathi, M. (2014). The Malaysian Government's Initiative in Using Building Information Modeling (BIM) In Construction Projects. *Proceedings of International Structural Engineering and Construction*, 1(1). https://doi.org/10.14455/isec.res.2014.82

Liu, Y. (2024). Integration of Building Information Modelling (BIM) With Transportation and Facilities: Recent Applications and Future Perspectives. *Buildings*, 14(2), 541. https://doi.org/10.3390/buildings14020541

Liu, Z. (2024). Digital Twin Model and Its Establishment Method for Steel Structure Construction Processes. *Buildings*, 14(4), 1043. https://doi.org/10.3390/buildings14041043

Li, C., Yu, Z., Wu, H., Chen, Z., Xiao, B., & Tam, V. (2023). The Application of Bim in The AECO Industry. *Journal of Civil Engineering and Management*, 29(3), 202-222. https://doi.org/10.3846/jcem.2023.18076

Lu et al. (2020): "Developing a Digital Twin at Building and City Levels: Case Study of West Cambridge Campus" *Journal of Management in Engineering* (2020) doi:10.1061/(asce)me.1943-5479.0000763.

Mao, Z., González, V., & Zou, Y. (2022). Exploring A Digital Twin Framework for Lean Management of Constraints in Construction: A Literature Review. *IOP Conference Series Earth and Environmental Science*, 1101(8), 082019. https://doi.org/10.1088/1755-1315/1101/8/082019

Mihai, S., Yaqoob, M., Hung, D., Davis, W., Towakel, P., Raza, M., Karamanoğlu, M., Barn, B., Shetve, D., Prasad, R., Venkataraman, H., Trestian, R., & Nguyen, H. (2022). Digital Twins: A Survey on Enabling Technologies, Challenges, Trends and Future Prospects. *IEEE Communications Surveys & Tutorials*, 24, 2255-2291. https://doi.org/10.1109/COMST.2022.3208773.

Maz, J. (2013). Employing A Grounded Theory Approach: Core Characteristics. *British Journal of Cardiac Nursing*, 8(9), 453-458. https://doi.org/10.12968/bjca.2013.8.9.453

Morgan, D. (1997). Focus Groups as Qualitative Research. *SAGE Publications*, Inc.https://doi.org/10.4135/9781412984287

Naeem, M. and Ozuem, W. (2021). Understanding Misinformation and Rumors That Generated Panic Buying as a Social Practice During Covid-19 Pandemic: Evidence from Twitter, Youtube and Focus Group Interviews. *Information Technology and People*, 35(7), 2140-2166. https://doi.org/10.1108/itp-01-2021-0061

Nguyen, T. and Nguyen, D. (2021). Barriers in BIM Adoption and The Legal Considerations in Vietnam. *International Journal of Sustainable Construction Engineering Technology*, 12(1). https://doi.org/10.30880/ijscet.2021.12.01.027

Oraee, M., Hosseini, M., Edwards, D., Li, H., Papadonikolaki, E., & Cao, D. (2019). Collaboration Barriers in Bim-Based Construction Networks: *A Conceptual Model. International Journal of Project Management*, 37(6), 839-854. https://doi.org/10.1016/j.ijproman.2019.05.004

Pan, Z., Shi, J., & Jiang, L. (2020). A Novel HDF-Based Data Compression and Integration Approach to Support BIM-GIS Practical Applications. *Advances in Civil Engineering*, 2020, 1-22. https://doi.org/10.1155/2020/8865107

Qing-sheng, X., Zhou, X., Wang, J., Gao, X., Chen, X., & Li, C. (2019). Matching Real-World Facilities to Building Information Modeling Data Using Natural Language Processing. *IEEE Access*, 7, 119465-119475. https://doi.org/10.1109/access.2019.2937219

Rahim, N., Ismail, S., Subramaniam, C., Habib, S., & Durdyev, S. (2023). Building Information Modelling Strategies in Sustainable Housing Construction Projects in Malaysia. *Sustainability*, 15(3), 2313. https://doi.org/10.3390/su15032313

Ryzhakova, G., Malykhina, O., Pokolenko, V., Rubtsova, O., Homenko, O., Nesterenko, I. & Honcharenko, T. (2022). Construction Project Management with Digital Twin Information System. *International Journal of Emerging Technology and Advanced Engineering*, 12(10), 19-28. https://doi.org/10.46338/ijetae1022_03

Schlenger, J., Yeung, T., Vilgertshofer, S., Martinez, J., Sacks, R., & Borrmann, A. (2022). A Comprehensive Data Schema for Digital Twin Construction. *The 29th EG-ICE International Workshop on Intelligent Computing in Engineering*. https://doi.org/10.7146/aul.455.c194

Shahat, E., Hyun, C., & Yeom, C. (2021). City Digital Twin Potentials: A Review and Research Agenda. *Sustainability*. https://doi.org/10.3390/SU13063386.

Stalmeijer, R., McNaughton, N., & Mook, W. (2014). Using Focus Groups in Medical Education Research: Amee Guide No. 91. *Medical Teacher*, 36(11), 923-939. https://doi.org/10.3109/0142159x.2014.917165

Tang, S., Shelden, D. R., Eastman, C., Pishdad-Bozorgi, P., & 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*. Vol. 101, Pp 127-139

Tripathi, I., Froese, T., & Mallory-Hill, S. (2023). Applicability of BIM-IoT-GIS Integrated Digital Twins for Post Occupancy Evaluations. *Frontiers in Built Environment*, 9. https://doi.org/10.3389/fbuil.2023.1103743

Teo, Y., Yap, J., An, H., Yu, S., Zhang, L., Chang, J. & Cheong, K. (2022). Enhancing The MEP Coordination Process with BIM Technology and Management Strategies. *Sensors*, 22(13), 4936. https://doi.org/10.3390/s22134936

Urquhart, C., Lehmann, H., & Myers, M. (2010). Putting The 'Theory' Back into Grounded Theory: Guidelines for Grounded Theory Studies in Information Systems. *Information Systems Journal*, 20(4), 357-381. https://doi.org/10.1111/j.1365-2575.2009.00328.x

Vincent, D., Ojo, S., & Omeje, H. (2020). Assessing The Utilization of Building Information Modelling Software for Project Planning in Construction Industries in Ondo State. *Journal of Advanced Research in Economics and Administrative Sciences*, 1(2), 134-140. https://doi.org/10.47631/jareas.v1i2.108

Wei, Y. and Lei, Z. (2022). An Off-Site Construction Digital Twin Assessment Framework Using Wood Panelized Construction as A Case Study. *Buildings*, 12(5), 566. https://doi.org/10.3390/buildings12050566

Wu, Z., Ren, C., Wu, X., Wang, L., Zhu, L., & Lv, Z. (2021). Research On Digital Twin Construction and Safety Management Application of Inland Waterway Based On 3d Video Fusion. *IEEE Access*, 9, 109144-109156. https://doi.org/10.1109/access.2021.3101653

Yan, J., Zhou, J., Li, Y., Xu, C., Sun, Y., & Liu, B. (2022). Research On Intelligent Pumped Storage Power Station Based On Digital Twins Technology. *Journal of Physics Conference Series*, 2237(1), 012022. https://doi.org/10.1088/1742-6596/2237/1/012022

Yi, J. (2021). Intelligent Building Construction Management Based On BIM Digital Twin. *Computational Intelligence and Neuroscience*, 2021, 1-11. https://doi.org/10.1155/2021/4979249

Yeung, T., Martinez, J., Sharoni, L., & Sacks, R. (2022). The Role of Simulation in Digital Twin Construction. *The 29th EG-ICE International Workshop on Intelligent Computing in Engineering*. https://doi.org/10.7146/aul.455.c215

Yu, C. (2024). Intelligent Analysis of Construction Safety of Large Underground Space Based On Digital Twin. *Buildings*, 14(6), 1551. https://doi.org/10.3390/buildings14061551

Zakharchenko, A. and Stepanets, O. (2023). Digital Twin Value in Intelligent Building Development. *Advanced Information Systems*, 7(2), 75-86. https://doi.org/10.20998/2522-9052.2023.2.11

Zhu, J. and Wu, P. (2021). Towards Effective BIM/GIS Data Integration for Smart City by Integrating Computer Graphics Technique. *Remote Sensing*, 13(10), 1889. https://doi.org/10.3390/rs13101889