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The Implementation of Digital Twin Technology in Construction Projects in Malaysia

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Abstract

The Malaysian construction industry continues to face persistent challenges such as project delays, cost overruns, inefficient asset utilization, and reliance on conventional maintenance practices due to limited real-time data integration To address these challenges, the adoption of advanced technologies has emerged as a transformative approach in reshaping construction project management by enhancing efficiency, reducing risks, and improving overall project performance.Digital Twin technology refers to a digital representation of physical assets that integrates real-time data to enable monitoring, simulation, and informed decision-making throughout the asset lifecycle. This study aims to explore the implementation of Digital Twin technology in Malaysia's construction industry, focusing on its potential benefits and adoption strategies. A qualitative research approach was employed, involving semi-structured interviews with industry experts, and the collected data were analyzed using thematic analysis to identify key patterns and industry trends. The findings reveal that although Digital Twin technology offers significant advantages, including predictive maintenance, real-time monitoring, and lifecycle optimization, its implementation is constrained by high initial costs, limited technical expertise, and low awareness among industry stakeholders. In conclusion, this study highlights that while Digital Twin technology possesses transformative potential for Malaysia's construction industry, its successful adoption requires strategic planning, policy support, and enhanced industry readiness.

1. Introduction

Digital Twin (DT) technology is emerging as a breakthrough in the worldwide construction industry , allowing for better decision-making and real-time monitoring through digital copies of tangible assets (Tao *et al.*, 2018). Due to a lack of utilization of digital tools, the construction industry in Malaysia continues to have problems such project delays, cost overruns, and inadequate asset management (Ali *et al.*, 2024). Therefore, the adoption of DT technology is increasingly necessary in the Malaysian construction industry to address persistent issues such as project delays, cost overruns, and inefficient asset management by enabling real-time monitoring, data-driven decision-making, and improved lifecycle management of construction assets (Tao *et al.*, 2018; Ali *et al.,* 2024). The purpose of this study is to evaluate DT's present benefits, challenges, and ways of implementing DT. Along with providing insights to encourage wider industry adoption, it also examines how DT can help national digital goals likeConstruction Industry Transformation Programme (CITP) and MyDigital (MAMPU, 2021; CIDB, 2020).

2. Literature Review

Digital Twin (DT) is an emerging technology that creates a real-time digital replica of a physical object, system, or process. Using data from sensors and Internet of Things (IoT) devices, DT enables monitoring, simulation, and optimization to support better decisions, predictive maintenance, and improved performance. In industries like construction, it enhances efficiency, reduces costs, and improves asset management throughout the lifecycle. McKinsey & Company, 2020).

2.1 Core Components of Digital Twin

A Digital Twin (DT) integrates physical and digital systems to support real-time monitoring, simulation, and optimization. Below are the key components that make DT function effectively:

• Physical Entity. This is the actual object or system being modeled, such as a building, bridge, or machinery in a construction project. It continuously produces real-world data through its operation. This data is crucial because the digital twin must reflect the true condition and behavior of the physical asset. Without physical entity, there would be no reference for the digital version to represent (Tao *et al*., 2018).

•The digital model is a virtual replica of the physical asset. It is built using tools like Building Information Modeling (BIM) and Computer-Aided Design (CAD). It stores detailed information such as shape, structure, materials, and energy performance. This model helps engineers and project managers simulate scenarios, check performance levels, and make better planning decisions (Sacks *et al*., 2020).

• Visualization Interface, The DT must be accessible and understandable to humans. This is where dashboards, 3D models, and Augmented or Virtual Reality (AR/VR) tools come in. These visual platforms help stakeholders like engineers, contractors, or clients interact with the digital twin easily, view real-time updates, and make collaborative decisions. It enhances communication and reduces misunderstandings in complex projects (Ghaffarian Hoseini *et al*., 2020).

•context, necessary for enhancing project efficiencies, optimizing lifecycle costs, and promoting the development of smart and sustainable infrastructure.

2.2 Benefits of Digital Twin Implementation

Digital Twin (DT) technology provides a wide range of benefits to the construction industry. It helps shift traditional construction practices toward smarter, real-time, and data-driven processes. These improvements support better decision-making, cost savings, sustainability, and project efficiency across the entire asset lifecycle (Tao *et al*., 2018; Fuller *et al*., 2020).

2.2.1 Enhanced Project Efficiency and Productivity

DT improves the way construction projects are monitored and managed. Through real-time updates from sensors and IoT devices, project managers can track site progress, worker productivity, and material usage. If a delay or issue occurs like material shortage or design error the system can quickly alert the team. This early detection reduces rework, improves scheduling accuracy, and leads to more effective use of time, labor, and equipment (Boje *et al*., 2020).

2.2.2 Cost Reduction and Lifecycle Asset Optimization

One of DT's strongest advantages is reducing long-term costs. Instead of fixed schedules for equipment maintenance, DT enables predictive maintenance by using real-time data to detect when a system or part needs servicing. This reduces unnecessary repairs and helps avoid costly breakdowns. Over time, it extends the lifespan of the building or infrastructure. Additionally, DT can simulate different investment scenarios, helping stakeholders choose the most cost-effective strategies for both construction and operation (Opoku *et al.,* 2021).

2.2.3 Risk Mitigation and Improved Safety

Safety is a major concern in construction. DT helps by continuously monitoring environmental and structural conditions on-site. It can alert workers if a structure is under stress or if an unsafe condition is developing, such as high vibration or temperature. DT systems can also simulate emergency scenarios like fire or flood to prepare response plans. This proactive approach minimizes risks and ensures faster, safer responses in high-risk projects such as tunnels, high-rises, or complex mechanical installations (GhaffarianHoseini et al., 2020).

2.2.4 Sustainability and Environmental Performance

DT technology plays an important role in reducing the environmental impact of construction. It tracks and analyzes energy use, water consumption, waste generation, and carbon emissions in real time. This allows building managers and engineers to take corrective action such as adjusting lighting, ventilation, or water usage to reduce environmental impact. It also supports compliance with sustainability frameworks like the Green Building Index (GBI) in Malaysia and the UN's SDG 11 (Sacks *et al*., 2020). DT helps in designing buildings that are not only efficient but also environmentally responsible.

2.3 Challenges in Digital Twin Adoption

Despite growing industry interest in the use of Digital Twin (DT) technology, adoption in Malaysia remains limited. There are financial, technical, and organizational challenges to be overcome to promote its adoption (Boje *et al*., 2020; Lu *et al*., 2020).

2.3.1 High Capital Investment and Financial Constraints

One of the principal challenges in DT adoption is the very high initial and operational costs. While companies need to invest in hardware such as sensors, software platforms, and cloud-based systems, ongoing costs related to system maintenance and technical support increase financial burdens (Deng *et al*., 2021; Sepasgozar *et al.,* 2020). These costs are usually very hard for small and medium-sized construction firms to afford; thus, most of them continue depending on conventional construction practices (CIDB Malaysia, 2021).

2.3.2 Lack of Skilled Workforce and Digital Competency

The implementation of the DT in the industry requires a labor force with high digital skills in relation to data analysis, BIM, and management of digital systems. On the contrary, most of the building industry practitioners in the country possess inadequate digital knowledge, hindering the successful use of the DT systems in the industry (Oesterreich & Teuteberg, 2016; Ismail, 2024). Despite efforts by the country towards improving the digital knowledge in the industry, progress in this aspect is relatively low (CIDB Malaysia, 2021).

2.3.3 Interoperability and Data Integration Issues

DT systems incorporate intensive data from BIM, IoT technologies, and other project management systems. In case different systems lack compatibility, the process of data transfer is inefficient as well as prone to various errors (Lu *et al.,* 2020; Boje *et al*., 2020). Such difficulties can be further worsened due to the lack of compatibility among different software systems being employed by construction organizations (Deng et al., 2021).

2.3.4 Cybersecurity and Data Privacy Concerns

DT platforms manage large volumes of sensitive data, including operational, structural, and performance information. Without robust cybersecurity measures, such data may be vulnerable to threats such as hacking, data breaches, and unauthorized access (Bolton *et al*., 2018; Love *et al*., 2019). Many construction firms lack comprehensive data protection frameworks, making organizations cautious about adopting DT technologies (Sepasgozar *et al*., 2020).

2.4 Ways to enhance Digital twin Implementation

2.4.1 Capacity Building and Training

Continuous training and up-skilling programs help enhance digital literacy around construction and enable professionals in using Digital Twin (DT) solutions more effectively. This helps in the diminishment of reliance on third-party companies, minimization of errors, and thereby maximization of efficiency in projects (Oesterreich and Teuteberg, 2016; Boje *et al*., 2020).

2.4.2 Organisational Support and Leadership

Leadership commitment is crucial in motivating individuals within an organisation to accept DT technology. The presence of commitment to digital technology within an organisation ensures that there is less resistance to change, decision-making is systematic, and implementing DT is aligned with organisational plans (Love *et al.,* 2019).

2.4.3 Improvement of Digital Infrastructure

The digital infrastructure guarantees real-time data transactions in the system, which is very important for the efficiency of DT systems. The present digital infrastructure improves the accuracy of data and the functionality of systems (Deng *et al*., 2021; Lu *et al*., 2020).

2.4.4 System Integration and Interoperability

Improved interoperability between DT, BIM, and IoT platforms makes data integration among the various systems much easier. This makes coordination, data consistency, simulations, and decision-making easier and more accurate (Boje *et al*., 2020; Lu et al., 2020).

3. Research Methodology

This section describes the data collection methods, instrumentation, and data analysis procedures, and ethical considerations, ensuring a rigorous approach to fulfilling the study purposes.

3.1 Data Collection Methods

3.1.1 Primary Data

Primary data is data collected directly from original sources for a specific research purpose, ensuring relevance and accuracy to the study objectives (Creswell & Creswell, 2018). The data were collected through semi-structured interviews with selected construction professionals, including project managers, engineers, and consultants from private sectors. Purposive sampling was used to select participants with experience in Digital Twin or smart construction technologies. Interviews were conducted online using Google Meet, lasting up to 45 minutes, and were recorded with participants' consent.

3.1.2 Secondary Data

Secondary data is data that has been previously collected and published by other researchers or organizations for purposes other than the current study (Saunders, Lewis, & Thornhill, 2019). Secondary data were obtained from academic journals, conference proceedings, industry reports, and government documents such as the Construction Industry Transformation Programme (CITP), MyDigital Blueprint, and the Malaysia Smart City Framework. These sources provided supporting evidence and contextual understanding of Digital Twin (DT) adoption in Malaysia.

3.2 Data Analysis

Following the completion of the interviews, thematic analysis, a widely used qualitative data analysis method, was employed to identify, analyze, and interpret patterns (themes) within the dataset (Braun & Clarke, 2019; Braun & Clarke, 2021). This involved listening to the recordings, generating transcripts, followed by several rounds of scrutiny by close reading to familiarise oneself with the results. Prominent phrases and ideas that emerge in relation to themes, such as a lack of digital skills, advantages in real-time monitoring, and too-high costs in implementation, have been captured and organised in an orderly way and interpreted accordingly (Creswell, 2014).

The application of thematic analysis ensures the objectives are fulfilled in the study since it enables the investigation of respondents' views on the implementation of Digital Twin (DT) technology. The approach enables the recognition of practices adopted, challenges, and possible ways to improve the use of DT technology in the Malaysian construction industry (Yin, 2018).

4 Results and Findings

4.1 Respondents' Background

The selection of respondents with relevant educational background and industry experience is crucial in ensuring the reliability and validity of qualitative research findings (Creswell & Poth, 2018). In the context of construction digitalisation, professionals such as engineers, project managers, and consultants play a significant role in the adoption and implementation of emerging technologies such as Digital Twin (DT), as they are directly involved in decision-making and project coordination processes (Sacks *et al.,* 2020). Therefore, selecting respondents from these professional backgrounds is appropriate for achieving the objectives of this study.

The purpose of collecting respondents background information is to identify their background and experience using Digital Twin (DT) technology.

Table 1 *Respondent background*

Respondent (R)	Education	Position	Experience in the current	Role in digital twin

			position	project
R1	Bachelor's Degree in Civil Engineering	Engineer	5 years	Engineer
R2	Bachelor's Degree in Construction Management	Project manager	3 years	Project manager
R3	Bachelor Degree in Engineering Management	Engineer	7 years	Engineer
R4	Bachelor's Degree in Quantity Surveying	Construction consultant	3 years	Project manager
R5	Bachelor's Degree in Civil Engineering	Project manager	4 years	Project manager

Table 1 summarizes the profiles of the five respondents in this study. In general, the respondents possess relevant education and professions with years of experience in the construction industry, thereby making them the best persons to investigate on the implementation of DT. All respondents possess a minimum educational attainment of a Bachelor's degree with undergraduate studies in Civil Engineering, Construction Management, and Quantity Surveying, which are relatively relevant to construction project delivery and digital technology application.

The respondents represent key positions within construction projects, including engineers, project managers, and a construction consultant. These roles are closely associated with decision-making, project coordination, and the adoption of digital technologies, particularly in relation to DT implementation. The respondents' experience in the current position ranged between 3 and 7 years, indicating that they have adequate practical exposure to construction processes and are also actively involved in current industry practice.

Additionally, the roles that the respondents have played in digital twin-related activities involve roles as engineer and project manager. This serves as an indicator that the respondents have been directly involved in the use of digital systems and the management of projects that involve digital twins. Therefore, the background of the respondents makes them relevant sources to enhance the reliability of the results that have been gathered through the interview process and ensure that the results obtained in this research have relevance in the context of the Malaysian construction industry.

4.2 Benefits of implementing Digital Twins in construction projects in Malaysia

The benefits as shown in Table 2 below.

Table 2 *Benefits of implementing Digital Twins in construction projects in Malaysia*

No.	Elements	R1	R2	R3	R4	R5
1	Improves real-time project monitoring	✓	✓	✓	✓	✓
2	Enhances decision-making through accurate project data	✓	✓	✓	✓	✓
3	Coordination and communication among project stakeholders	✓	✓	✓		✓
4	Supports early detection of project risks and issues	✓	✓		✓	✓
5	Reduces errors, rework, and construction delays	✓		✓	✓	✓
6	Improves planning and scheduling efficiency	✓	✓	✓	✓	✓

7	Supports predictive maintenance and asset performance		✓	✓	✓	✓
8	Enhances resource management and cost control	✓	✓		✓	✓
9	Contributes to improve project quality and performance	✓	✓	✓	✓	✓

Based on Table 2, all respondents agree that implementing DT improves real-time project monitoring. All respondents agreed that DT provides enhanced visibility into project progress through accurate, reliable data, thereby enabling informed decisions and efficient project control. This is an indication of a high level of agreement among the respondents regarding the technicality of DT in projects.

To support this finding, R1 emphasized the following role of DT in improving real-time monitoring and identification of issues:

"...Digital Twin contributes to enhance real-time monitoring of activities within construction, with possible problems being picked up at an early stage..." (R1)

On the same topic, R2 highlighted the fact that DT enhances the accuracy of decision-making through precise and credible information regarding the project:

"*...Digital Twin enables better decision-making through providing accurate and updated project information...*" (R2)

Moreover, most of them (R1, R2, R3 and R5) reported that DT enhances the coordination and communication level among project stakeholders, which consequently facilitates smoother project execution. This point was stressed more by R3, who showed that DT allows for better sharing of information and reduces misunderstandings:

"*Digital Twin enables better coordination and communication among the project stakeholders during project execution*." (R3)

The findings also reveal that DT supports early detection of project risks, thereby reducing errors, rework, and construction delays. R4 explained that DT enhances planning and project control, which improves overall project performance:

"*...twin-digital contributes to better planning and general control of the project, acquiring a better result in this ...*" (R4)

Moreover, DT was perceived by R1, R2, R4 and R5 as one tool for enhancing resource management, cost control, and planning efficiency, though with some variations in the responses, which perhaps means such benefits come with the extent of DT implementation and project contexts. Irrespective of these variations, all respondents agreed to a positive contribution of DT in project quality and performance.

The findings from this study clearly show that the implementation of DT is of great value when it comes to real-time monitoring, decision making, coordination, and performance, and it is playing a very important role within the context of the digital transformation and smart construction movement within the Malaysian construction industry. The fact that the responses were consistent from all the respondents shows that there was a level of data saturation.

4.3 Challenges encountered when implementing Digital Twin technology

Details of the challenges are shown in Table 3 below.

Table 3: *Challenges when implementing Digital Twin technology in construction projects.*

No.	Elements	R1	R2	R3	R4	R5
1	High initial implementation cost	✓	✓	✓	✓	✓
2	Ongoing maintenance and system upgrade costs	✓	✓		✓	✓
3	Lack of digital skills and technical expertise	✓	✓	✓		✓

4	Difficulty in integrating DT with existing systems	✓	✓	✓	✓	
5	Interoperability issues between BIM, IoT, and DT platforms	✓		✓	✓	✓
6	Data accuracy and real-time data availability issues		✓	✓	✓	✓
7	Cybersecurity and data privacy concerns	✓		✓	✓	✓
8	Resistance to change within organisations	✓	✓		✓	✓
9	Limited awareness of DT benefits among stakeholders	✓	✓	✓		✓
10	Lack of clear government guidelines and standards	✓	✓	✓	✓	✓

Based on the respondents' views, identifies investment cost as the most important problem in implementing the Digital Twin (DT) technology in the industry. The respondents concur that the cost involved in the implementation of DT solutions discourages the organisation from adopting the technology. The researcher has tried to support the identification of the problem with the views expressed by R1 and R4, who clarified that the investment cost has been a restrictive factor in the implementation of the DT technology in the following manner:

"*…The initial investment is a big challenge. Obviously, the management would first look at the budget, and the Digital Twin system will require a high level of investment…*" (R1)

"*.I think cost is one of the biggest factors that play a role when it comes to the implementation of a Digital Twin. Even if it is beneficial, cost is still a priority…*" (R4)

Although there was this consensus, R2 came up with a different view that while the initial cost of investment is high, the long-term benefit justifies the cost. This view is supported by the following statement:

"*.Although high at first, the investment pays off in the long term because Digital Twin helps improve monitoring and decision-making while reducing future operational issues*." (R2)

"…Government's incentives or grants, that will really help. They can make the financial support less of a burden in terms of justifying investments by companies in the Digital Twin technology…" (R1)

".If there were grants, tax incentives, or low-interest loans, it would definitely incentivize organizations to adopt Digital Twin systems." (R4)

These findings therefore align with the prior research of Ojo et al. (2025) regarding the fact that advanced digital technologies, especially those incorporated into real-time data systems and IoT platforms, need vast capital investment to be implemented, which often becomes a huge barrier for organisations.

Aside from budget issues, R3 and R4 have emphasized complexity and system integration issues. As cited by the respondents, issues related to the integration of DT with other systems, most specifically when using various software platforms, are challenging:

".The process of implementation is quite technical. We encountered some challenges when blending data from various systems, and at times the data did not sync properly…" (R3)

"Compatibility is a major factor. There could be compatibility issues in some existing systems with new Digital Twin technologies. There could be technical issues when it operates…" (R4)

Furthermore, the lack of expertise in the workforce is also identified to impact the effectiveness of the DT system. Expertise in the field has been recognized as an important factor in the operation of the more complex Digital Twin systems. According to R2 and R3:

"…If staff do not have digital competences, then it will have an effect on efficiency and result in mistakes, which in effect raises the cost of digital twin adoption…" (R2)

"*…Not all project teams are aware of the Digital Twin systems available to us. More training is required, although we are still dependent on third-party suppliers for technical problems…*" (R3)

Next, issues related to interoperability between BIM, IoT, and Digital Twin (DT) platforms were also identified as a significant challenge in the implementation of Digital Twin technology. According to the respondents, this issue arises when different systems are unable to communicate and exchange data seamlessly due to differences in software platforms, data formats, and technical standards used in the construction industry. This lack of interoperability often leads to data inconsistency and disrupts real-time information flow, which subsequently affects the accuracy of simulation and decision-making processes within Digital Twin systems.

This issue is supported by R3, who stated that:
"…The process of implementation is quite technical. We encountered some challenges when blending data from various systems, and at times the data did not sync properly…" (R3)

In addition, R4 further emphasized system compatibility issues by stating that:
"Compatibility is a major factor. There could be compatibility issues in some existing systems with new Digital Twin technologies. There could be technical issues when it operates…" (R4)

Other concerns related to data security and, linked to these, cybersecurity risks having in mind the broad utilization of real-time and cloud-based data in DT systems. For these specific subjects, R2 and R3 emphasized risks of data breach and system security:

"*...Digital Twin systems generate data continuously. In case of a breach, it might influence the accuracy of the data and general monitoring of the project.*" (R2)

"*…As not all Digital Twin platforms are cloud-based, we would have some concern about data security and access control…*" (R3)

To minimize such risks, most respondents followed basic cybersecurity measures currently in place. These include system access restriction, password protection, and regular updating, described by R1 and R4:

"…*We limit system access to authorized personnel only, and the vendor guarantees minimum security measures like password protection and updates…*" (R1)

"…*Access control and guidelines about IT security stand in order to minimize the cybersecurity risks, though the system is not too complex*…"(R4)

Some respondents also argued that better financial rewards, easier regulatory policies, and awareness campaigns would facilitate the adoption of the DT technology. For example, R2 emphasized the following points:

Incentives and recognition:

"*… A recognition or awards program for digital and smart construction practices could encourage organisations to adopt theDigital Twins system…*" (R2)

But R3 was worried that the absence of mandatory regulations hinders DT acceptance, as expressed by the following statement from R3:

"*…However, there is no particular regulation that forces the use of Digital Twin technology by the construction companies. Currently, it is still an optional, not mandatory requirement…*" (R3)

Lastly, the participants agreed that resistance within an organisation and a lack of awareness remain major challenges in the implementation of DT. Support from the management was cited to aid in the speedy implementation of DT, as quoted by R4:

"*...When supported in implementing Digital Twins, it will run smoothly. Nonetheless, lack of awareness among workforce members might hinder the implementation rate....*" (R4)

The similarity in the challenges raised by the respondents indicates thematic saturation, where consistent concerns were observed despite differences in their organisational roles and the types of construction projects they were involved in. This suggests that the issues identified are not isolated cases, but rather common and recurring barriers in the adoption of technology within the construction industry.

4.4 Ways for improving the implementation of Digital Twins in construction projects in Malaysia

Table 4: *Ways for improving the implementation of Digital Twins in construction projects in Malaysia*

No.	Elements	R1	R2	R3	R4	R5
1	Provision of continuous training and upskilling programmes.	✓	✓	✓	✓	✓
2	Increase management support and leadership commitment.	✓	✓	✓		✓
3	Improvement of digital infrastructure and system integration.	✓	✓	✓		✓
4	Development of clear organisational strategies for DT adoption.	✓		✓	✓	✓
5	Collaboration with technology providers and industry partners.	✓	✓		✓	✓
6	Government incentives and financial support schemes.		✓	✓	✓	✓
7	Establishment of clear guidelines and standards for DT implementation.	✓		✓	✓	✓
8	Promoting awareness and knowledge-sharing initiatives.		✓	✓	✓	✓
9	Gradual and phased implementation of Digital Twin systems.	✓	✓		✓	✓
10	Strengthening change management and organisational readiness	✓	✓	✓		✓

Table 4 shows that, from a strategical perspective, capacity building, organisational support, and government involvement are the leading strategies that could enhance DT technology implementation in construction projects. All respondents agreed that continuous training and upskilling programmes are essential to improve workforce readiness and ensure effective use of DT systems, hence indicating human capital development plays an important role in supporting digital transformation.

To support this, R1 explained how training and gradual implementation may help to reduce resistance and enhance readiness:

".Continuous training and gradual implementation would help staff understand and adapt to Digital Twin systems." (R1)

Strong support for management and leadership commitment were the other identified enablers of DT adoption. Without this clear organizational direction, the implementation efforts of DT will be resisted and would therefore lack continuity. This view was supported by R2, who commented:

".Management support is necessary in order for people to take the implementation of Digital Twin seriously and actually plan it properly." (R2)

In this regard, another crucial consideration that was reaffirmed by the respondents is the need to ensure better digitized infrastructure in relation to the DT concept. This is because, as indicated in Table 4, some respondents were in agree on the need to ensure a smooth integration of DT platforms with other digitized systems in a manner that supports data accuracy. This was especially pointed out by R4, who said that:

".Improving the digital infrastructure and co-operating with technology suppliers can be key to ensuring that Digital Twin systems operate correctly…" (R4)

The results also show a high degree of agreement on the significance of government incentives, the availability of guidelines, and standardized frameworks to promote the adoption of DT in organisations. The consensus on various factors to ease the adoption of DT technology in organisations was echoed by R3, which mentioned that:

"…Clear guidelines and standards would help organizations understand how to implement Digital Twin consistently… ."(R3)

Moreover, the need for awareness campaigns, industry collaborations, and phase-wise implementation would help facilitate the adoption of DT. Despite some variation in responses related to preferred implementation methods, it is evident that there is an imperative need for collaborative efforts by the organizational and industry sectors as well as the government to ensure sustained adoption of digital twins within the Malaysian construction industry.

The fact that strategies are consistent across participants suggests that thematic saturation has been reached and that the recommendations are indicative of generally accepted strategies as opposed to preferences that are organization-specific. This indicates that the recommendations are generally valid and applicable.

5 Conclusion

This study has successfully fulfilled its purposes by investigating the adoption of Digital Twin (DT) technology in the Malaysian construction industry. The results clearly demonstrate that DT technology offers numerous benefits, including optimizing monitoring, decision-making, coordination among project stakeholders, and project performance. Apart from these benefits, the study also listed the major challenges associated with the adoption of DT technology, such as the cost of implementation, lack of digital skills, system integration, and regulatory issues. At the same time, the study offered effective strategies to optimize the adoption of DT technology by providing capacity development, support from the organizations, development of digital infrastructure, and government support.

This study is important as it provides valuable insights for industry stakeholders and policymakers in improving the readiness and effectiveness of Digital Twin implementation within the Malaysian construction sector. Future research, it is recommended that further studies focus on empirical case studies and large-scale quantitative analysis to evaluate the long-term impact and scalability of Digital Twin adoption across different types of construction projects in Malaysia.

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Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: **study conception and design:** Iezza Nadia Binti Jamri, Aryani Binti Ahmad Latiffi; **data collection:** Iezza Nadia Binti Jamri; **analysis and interpretation of result**; Iezza Nadia Binti Jamri; **draft manuscript preparation:** Iezza Nadia Binti Jamri, Aryani Binti Ahmad Latiffi. All authors reviewed the results and approved the final version of the manuscript.

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