Integrating Digital Twins in Real Estate: Revolutionising Property Management

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Abstract

The use of digital twin technology in property management is examined in this study, with a focus on the Malaysian real estate market. Thus, the goal is to use digital twins with real-time monitoring, predictive maintenance, and building system optimisation to overcome the inefficiencies of traditional property management. The study has various significances, first as it fulfils the research goals of not only pinpointing the inefficiencies and problems that the traditional property management process in Malaysia is currently facing but also structuring a path towards having the advanced digital twin technology introduced to the given field. In general, the study examined both residential and commercial properties, including office buildings and high-rise apartments. A mixed methodology is used in the study, which includes quantitative data from 100 tenants and qualitative interviews with 50 property managers regarding the cost reduction, tenant satisfaction, and operational efficiency of digital twins. While quantitative data was subjected to descriptive and inferential statistical methods using SPSS as the preferred statistical package, qualitative data was subjected to thematic analysis. The results are maintenance expenses have decreased by 30%, tenant complaints have decreased by 25%, and operating expenses have decreased by 20%. These findings also highlight issues with key data integration, including scalability of digital twin applications, data security issues, and interoperability between legacy systems and digital twins. Despite the fact that the technology has many advantages, the study makes it evident that more research is required to fully examine cost-benefit analysis over an extended period of time and to determine whether the technology can scale across various property types. The results offer valuable perspectives for policymakers, property managers, and individuals seeking to incorporate these technologies into real estate management.

Keywords: Digital twin technology, Operational efficiency, Predictive maintenance, Property management, Tenant satisfaction

■1.0 INTRODUCTION

The emergence of digital twin technology is a remarkable development in the advancement of different sectors, more so in property management. Digital replicas of physical assets are effective in overseeing, modelling, and enhancing real estate properties. This emerging technology utilises data from sensors and IoT devices to construct real-time models that represent the state of physical structures, which makes it possible for the property managers to have an exceptional level of insight and oversight over the properties (Duch-Zebrowska & Zielonko-Jung, 2021). The advantages of using the digital twin technology are staggering, and some of these are: there will be better planned and more accurate maintenance of the building's infrastructure, which results in a great return on investment for the building owners. Many tenants frequently benefit from digital twin technology. According to Nurumova et al. (2022) and Pomè and Signorini (2023), tenants are more satisfied when maintenance delays are minimised and living conditions are optimised through predictive maintenance, quicker issue resolution, and real-time monitoring. Furthermore, Tahmasebinia et al. (2023) and Okeagu and Mgbemena (2022) found that digital twins contribute to energy efficiency and personalised smart living, which enhances tenant comfort and reduces operating expenses. Therefore, according to Mohamed and Ibrahim (2024), properties reported by digital twins have lower complaint rates and higher tenant retention rates. The expenses of running a building will also be cut down. Realising the significance of digital twins, various industries around the world are on the verge of embracing this technological advancement in property management (Hu et al., 2022; Mihai et al., 2022). Specifically, the integration of the digital twin technology in the Malaysian scenario holds potential to solve

some of the persisting problems in property management. The Malaysian property market has long-standing problems that remain relevant today, especially regarding maintaining efficiency and rising operational costs in both Kuala Lumpur and Johor Bahru. For example, the management of big commercial facilities entails prosthetic maintenance, which results in unforeseen breakdowns that inconvenience the occupants and affect their productivity. The nature of managing such properties is challenged by the tropical weather systems, which have a higher rate of deterioration of building infrastructure. Some of these challenges can be addressed by the use of digital twins since they offer real-time data and predictive analytics that enable property managers to prevent maintenance problems before they occur (Deng et al., 2021). This shift from reactive to proactive management is particularly important for enhancing the effectiveness and stability of property management within Malaysia (Okeagu & Mgbemena, 2022).

Many cases of traditional proactively managing property in Malaysia today involve using traditional methods whereby they carry out manual work, and some of the maintenance works are done in a reactive manner, hence making them inadequate and expensive (Mat Noor, 2013). These old-school practices often produce significant time lags in the handling of maintenance complaints, something that leaves many tenants dissatisfied and the business operation's cost of operations elevated. As the real estate market continues to evolve in the region, the country of Malaysia in particular, such inefficiencies can lead to considerable costs. Real-time adjustment of the systems in the property and receiving alerts when particular components are likely to fail in a building is made possible through digital twin technology. This capability not only prevents breakdowns in advance but also avoids a situation when, for example, a tenant is waiting for an elevator, minimises downtime, and increases tenants' satisfaction and operation efficiency (Pomè & Signorini, 2023). Nevertheless, to date, little is known regarding the various effects that digital twin technology may have on improving property management productivity in the Malaysian context. Another significant challenge in Malaysia's property management sector is the issue of high operating costs, especially as it relates to managing large properties in major cities, especially all those big cities such Johor Bahru and Kuala Lumpur (Noor et al., 2024). These costs are further magnified with reliance on the reactive approach to maintenance and again compounded by siloed systems that do not have interoperability of building management systems. For instance, big business buildings are inefficient, and in some instances, they have not been followed, thus the wastage and high bills on energy use. This is because digital twins enable property managers to have a holistic perspective of a building's systems, ensuring that resources are well utilised and there's minimal consumption of energy (Opoku et al., 2021). In terms of cost savings, optimising resource allocation is one of the primary drivers for incorporating digital twins into property management. According to Tahmasebinia et al. (2023), digital twins reduce energy and operating costs in commercial buildings by an average of 25%. Based on better resource use and energy efficiency, operating costs were observed to drop by 20% in the Malaysian results. Furthermore, it offers yearly savings of up to RM50,000 per property and makes it easier to monitor HVAC systems in real time (Okeagu & Mgbemena, 2022). This has to do with the current state of affairs in Malaysia, where there is a problem with energy costs that has a significant impact on property managers. First of all, digital twins allow property managers to cut expenses while also advancing the nation's green agenda (Tahmasebinia et al., 2023).

Tenant satisfaction is another area where digital twin technology can make a significant difference. In order to prevent vacancies, it is crucial that the quality of services and their responsiveness meet acceptable levels of tenant satisfaction, given the rising demands and expectations of tenants in Malaysia. Additionally, digital twins allow property managers to make prompt, proactive decisions and provide the necessary services from the tenant's point of view as effectively as possible (Pomè & Signorini, 2023). Predictive maintenance is one of the most significant advantages of digital twin technology for property management, among other advantages. Digital twins effectively prolong the asset's life by reducing downtime and anticipating potential system failures before they occur (Opoku et al. 2021). According to a study by Mihai et al. (2022), buildings that use digital twins have 40 percent fewer emergency repair incidents and 30 percent lower overall maintenance costs. These findings are corroborated by the study's 30% cost reduction. For instance, if a tenant complains that they are facing problems with their air conditioning unit through the application, then instead of having the property manager go preparing to work on the issue, a digital twin will enable the identification of the problem and the staff who will attend to the repair with the necessary tools and spare parts be dispatched promptly. High tenant satisfaction is achieved by this capability, which also minimises any inconvenience to tenants when diagnosing and fixing issues that they could have resolved themselves (Li et al., 2023).

Nonetheless, the results of this study are pertinent to a number of research gaps regarding the application of digital twin technology in Malaysian property management. Firstly, it offers practical findings on the use of digital twin in making maintenance solutions more effective, increasing tenant satisfaction, and decreasing costs for operating properties in the Malaysian context. Second, it provides an insight into the risks and threats associated with the implementation of digital twin in Malaysia and possible ways of addressing these challenges. Last but not least, it contributes to the existing literature by presenting findings that can help in establishing guidelines for implementing digital twin technology in property management. This research is relevant, especially in today's Malaysia, where the country is experiencing rapid urbanisation and moving towards the digital landscape in almost all industries. Through providing a critical exploration of the theoretical and empirical constructs of digital twin in the context of real estate assets, this study seeks to open the pathway for better, more sustainable, efficient, and pro-tenant-orientated property management practices in Malaysia. This research is important in several ways, as it meets the research objectives of directly identifying the inefficiencies and challenges that conventional property management practices in Malaysia are experiencing while also outlining a course for the installation of the sophisticated digital twin technology into the sector. By using the case studies and offering quantifiable data, the findings empowers the property managers with the facts and guidance required for risk assessment regarding the implementation of the digital twin solution. In addition, this study calls for more research and awareness on this area so that Malaysia's property management industries can maximally exploit digital twins and translate the benefits into better operational performance, tenant satisfaction, and sustainability (Mohamed & Ibrahim, 2024). The implications of this study are not only for property managers in the country but are also of particular significance to policymakers and stakeholders involved in the property development sector in Malaysia to encourage the adoption of technological advancement towards the achievement of sustainable property development.

■**2.0 LITERATURE REVIEW**

The literature on digital twin technology in real estate management underscores its transformative potential in several key areas such as predictive maintenance, tenant satisfaction, and operational cost reduction shown in Table 1. Digital twins, by creating real-time virtual models of physical assets, provide property managers with comprehensive data and predictive analytics that can significantly enhance property management efficiency. The benefits are then examined in this section using examples from the real world, including one in Malaysia that addresses the difficulties property managers encounter when integrating digital twins. The adoption of digital twin technology is supported by its ability to anticipate maintenance, which enhances and optimises operations in the context of real estate management. The studies are predicated on the idea that property managers can use digital twins to consume data in real time, which ultimately lowers maintenance costs and time, as well as short-term energy consumption. In essence, the use of digital twins in the real estate industry is much faster than the significantly reduced inefficiency of traditional property management (Hu et al., 2022; Deng et al., 2021).

Table 1 Overview of digital twin applications in real estate

Application	Benefits	Source
Predictive Maintenance	Reduced downtime, extended asset life	Dinter et al. (2022)
		Li et al. (2023)
		Mihai et al. (2022)
		Opoku et al. (2021)
Tenant Satisfaction	Enhanced living experience, quicker issue resolution	Li et al. (2023)
		Mihai et al. (2022)
		Nurumova et al. (2022)
		Opoku et al. (2021)
		Pomè & Signorini (2023)
Operational Costs	Lower energy consumption, optimised resource use	Deng et al. (2021)
		Hasan et al. (2020)
		Hu et al. (2022)
		Mohamed & Ibrahim (2024)

One crucial area that aids property managers in preventing the emergence of problematic equipment is maintenance prediction. According to Dinter et al. (2022), this kind of practice increases the asset's usable life and decreases the overall amount of time it is unavailable for effective operation. For example, the predictive maintenance solution can be used in Malaysian commercial real estate, particularly in buildings with extremely large structures and complex HVAC systems. Such systems can be modelled using digital twins that can track the performance of these systems and predict faults or failures that may occur; maintenance can also be performed during low traffic periods, thus making such systems effective while incurring less on maintenance expenses.

Tenant satisfaction quality can be enhanced and supported through the use of digital twins while enhancing the materials that are being provided and delivering more of what the tenant needs. Nurumova et al. (2022) further explain that through the use of digital twins, it is possible to achieve a faster problem-solving time due to the information on the condition of properties in real-time. In Malaysia, where more and more residential properties in the urban areas have integrated smart technology features, digital twins improve the tenant experience by providing efficient solutions to problems like leakages or electrical faults, among others. For instance, if a tenant complains of a faulty air conditioner, the digital twin can recommend a solution and direct the maintenance department towards fixing the issue in good time, leading to enhanced satisfaction among tenants and reducing rates of tenant turnover.

Table 2 Comparative Analysis of Conventional Management vs. Digital Twin-Enhanced Property Management

Aspect	Traditional Management	Digital Twin-Enhanced Management	Source
Maintenance Approach	Reactive	Predictive	Dinter et al. (2022)
			Mihai et al. (2022)
Data Utilisation	Limited	Extensive	Nurumova et al. (2022)
			Opoku et al. (2021)
			Pomè & Signorini (2023)
Tenant Interaction	Manual	Automated	Deng et al. (2021)
			Hasan et al. (2020)

Another advantage of implementing digital twin technology is the enhancement of reductions to operational costs. According to Hasan et al. (2020), digital twins are also useful in efficient utilisation of resources and minimisation of energy consumption. In Malaysia, energy costs are of big concern to property managers, and the analytics provided by the digital twins can come in handy to guide the managers on ways of cutting on energy utilisation. The digital twins can also control the functions in lighting and other related devices, such as HVAC, depending on the occupancy and hence can save a lot of energy. Efficiency savings do not only lower operational expenses but also enable property management companies to have sustainable goals.

As indicated in Table 2, digital twin has the ability to revolutionise property management practices. Nevertheless, there is not enough empirical research to determine these benefits with parameters and give deeper insights on how digital twins can be efficiently

incorporated into real estate management information systems. This gap is quite apparent in the Malaysian context, especially because the research in this area that is focused on local practices and issues is scarce. Thus, researchers should try to focus on this information gap so that they can provide Malaysian property managers with more viable solutions. Many international case studies have demonstrated that digital twins are a game changer, even though their use in Malaysia is still in its infancy. Digital twin-based systems have been used to develop large-scale commercial properties in Singapore, and it has been shown that these systems' maintenance workflows can be optimised with a 50% system failure rate (Mohamed & Ibrahim, 2024). Additionally, Dinter et al., (2022) conducted research in the USA that shows how the use of digital twins in smart buildings can lead to a 30% increase in tenant satisfaction, proactive service delivery, and a decrease in response times. Furthermore, these results suggest that these tactics may contribute to the human capital of Malaysia's real estate industry, particularly when it comes to the dense populations in cities that struggle with inadequate property management. However, some of the obvious advantages of digital twins pose a challenge to their adoption in the real estate industry. Modern digital twin technologies are not entirely compatible with many legacy property management systems, making data integration a major problem (Mohamed & Ibrahim, 2024). If there are privacy and data security issues, company executives must also address them. Continuous data collection from multiple sources is a feature of digital twins that increases cybersecurity risks (Nurumova et al., 2022). Another challenge is the high initial investment cost of implementing digital twin solutions, which requires upgrading extensive infrastructure and, finally, training personnel for operation and maintenance (Pomè & Signorini, 2023). For the adoption of digital twins in Malaysia's real estate industry to be successful, the aforementioned difficulties must be taken seriously.

Some of the challenges that are currently affecting the real estate industry in Malaysia include the problem of maintenance costs and the need to manage its resources optimally (Mat Noor et al., 2013). The following are some of the challenges that can be tackled by integrating digital twin technology in the property management industry: For instance, applying digital twin to execute and monitor management tasks in Kuala Lumpur high-rise buildings will help reduce excessive time consumption needed in performance, construction, and management. Incorporation of real-time data ensures that property managers are able to make the right choices for the properties under them. This integration can be used to make property management in Malaysia more efficient and less costly in the long run.

The literature shows that digital twin technology is seen to have a relative high potential in the field of real estate. The advantages of predictive maintenance, higher satisfaction of tenants, and lower costs of operation are quite clear; however, there is a lack of strong evidence to apply these in real-life scenarios. Specifically, in the given Malaysian context, this approach is expected to be effective in responding to the features of the challenges that property managers are facing, acting as the type of digital twining that can open the way to further advanced property management practices for the benefit of more efficient and sustainable outcomes. Looking at the general advancements in technology, the use of technology, especially in Malaysia's real estate industry, is also likely to adopt following the realisation of the need for innovation and efficiency.

■3.0 METHODOLOGY

This study employed a mixed-methods approach to comprehensively investigate the impact of digital twin technology on property management efficiency. By integrating qualitative interviews and quantitative surveys, the research aimed to capture a broad understanding of the subject. This methodology facilitated the collection of both numerical data and detailed personal insights, allowing for a more robust analysis of the effects of digital twin technology on property management practices.

3.1 Respondent Selection

The study targeted two distinct groups of stakeholders: It is so because the decision is consequential, distinguishing property managers and tenants. A sample size of 150 respondents was used, of which 50 were property managers while 100 respondents were the tenants in different residential and commercial premises. The property managers were selected depending on the basis of their experience and the type of properties they were managing. This stratification helped in making sure the study got information that was from both experts and inexperienced working professionals. Consequently, 40 percent or 20 respondents of the property managers have had their experiences for more than ten years; 35 percent or 18 respondents had experiences ranging from five to ten years, while 25 percent or 12 respondents had experiences for not more than five years. In addition, 30 respondents (60%) were property managers for the residential management sector, and 20 respondents (40%) were from the commercial management sector. To help digital twin researchers discern the inherent distinctions between residential and commercial properties in the use of digital twin technology, the division is crucial.

On the other hand, the tenant respondents for the study were chosen in such a way that the study captured the various expectations from the tenants. The tenants were categorised into three age groups: The age distribution of the sample was relatively young, with 18-30 year old participants comprising 30% of the sample, 31-50 year old participants constituting 50% of the sample, and the remaining 20% were 51 years and older. In addition, the tenants were classified by the type of property occupied, whereby 70% occupied residential property while 30% occupied commercial property. Therefore, this was done in an effort to give a comprehensive picture of the amity and enmity in the sense of satisfaction provided by this breakdown of property types and demographics regarding how tenants used digital twin technology in their homes and businesses.

3.2 Qualitative Interviews

Fifty property managers participated in in-depth interviews for the study's qualitative component. The purpose of the interviews was to thoroughly examine the professionals' experiences and challenges with the more conventional property management techniques. Furthermore, the purpose of the interviews was to find out how they view digital twin technology and how they think it can help them overcome the challenges they encounter on a daily basis.

Depending on the respondent's preference, the interviews lasted anywhere from 30 to 60 minutes, and they were conducted in person or through video conference. Because of the interview's flexibility, the data collection process was able to accommodate respondents' schedules, which in turn led to increased participation and richer data. The interviews were conducted using a series of open-ended questions to elicit in-depth and stimulating answers. The purpose of these questions was to encourage the property managers to talk honestly and share their actual experiences, without giving them any chance to respond in a biased manner.

The stratification of property managers based on experience level was a key component of the qualitative methodology. It was able to incorporate people with varying degrees of experience, from those who were relatively new to the field to those who had worked in it for a long time. Understanding how the experiences of different stakeholders may affect the potential adoption and implementation of digital twin technology in property management required a diversity of viewpoints.

3.3 Quantitative Surveys

The quantitative part of the research activity was to distribute questionnaires that were completed by the 100 tenants. Most of the surveys aimed at assessing the tenants' satisfaction with the existing property management services and their understanding of the digital twin concept. The questions were designed such that they were simple and direct, thereby not putting the respondent in a position where he/she would be inclined to give a particular type of answer. These were closed questions that enabled the researcher to collect numerical information and the open questions that gave the opportunities for tenants' qualitative comments. This section of the study was designed to assess tenants' levels of satisfaction with existing property management services and to evaluate their awareness, understanding, and perceptions of the digital twin concept.

The surveys were delivered online due to convenience because the selected site offers an easy, hassle-free way of completing the surveys. This distribution was also done through the internet so that as many people as possible could fill in the questionnaire at their own pace. To minimise the problem of nonresponse and decrease possible sources of measurement error, the survey questionnaire was pretested with a sample of tenants. This pilot phase enables one to determine whether or not their survey design has some problems or challenges, which tend to surface when the survey is conducted among a larger group of people.

The conducted survey was closed for two weeks, which is more than enough time for any tenant that has been asked to participate. Especially, it was critical in terms of achieving the maximum coverage of tenants as it applied a flexible time span, taking into consideration their diaries and providing more time for respondents' reflection. The division of the tenant respondents by demographic characteristics and property type guaranteed that the collected survey data reflected existing tenant satisfaction levels and consequences of adopting digital twin technology for tenants' living or working conditions. By segmenting tenant respondents according to demographic factors and property types, the study ensured that the collected data captured a representative view of satisfaction levels and provided insights into how digital twin technology could affect tenants' daily living or work environments.

3.4 Data Analysis

After gathering all data, the qualitative and quantitative aspects were compared with the help of the proper research tools in order to have the complete picture of the study objectives. As Creswell (2014) states, this mixed-methods technique made it possible to triangulate the findings and obtain a better understanding of the experience of the tenants and the property managers with the existing property management processes and opportunities of the digital twin technology.

3.4.1 Qualitative Data Analysis

The qualitative data were based mostly on answers obtained as a result of interviews carried out with property managers. The audiotaped recording of these interviews, verbatim transcriptions of these tapes, and the analytic procedure on such recordings are based on thematic analysis as defined by Braun and Clarke (2006). A thematic analysis is a technique used to identify and analyse any pattern (themes) in data and then report these parts. This approach was selected because it is flexible and appropriate to collect the subtle interpretations of property managers on the adoption of digital twins and the current issues of management.

The process was getting acquainted with the data, coming up with initial codes, the search for common themes, theme review, defining and naming of themes. The qualitative method also provided quality and content to the results, particularly where it came to the comprehension of managerial attitude and issues as well as expectations for the incorporation of technology in the administration of properties.

3.4.2 Quantitative Data Analysis

The analysis of quantitative data, which was developed on the basis of a structured questionnaire and given by 100 tenants, consisted of descriptive and inferential statistics. SPSS software was used to perform an analysis to provide the frequency, percentages, mean, and standard deviation to describe the demographic representation and distinct satisfaction level. Correlation and cross-tabulation (or inferential methods) were used to examine the connection between the satisfaction of tenants and whether they were aware or would be interested in using digital twin solutions (Field, 2013).

The general survey aimed at two fundamental parts: (i) satisfaction of tenants with the existing organisational services in handling the property and (ii) awareness and conceptual knowledge about digital twin technology. The closed-ended questions allowed gathering of quantifiable data, and some open-ended questions provided slightly qualitative information on them, which was then classified by key themes.

3.4.3 Incorporation of Qualitative and Quantitative Information

The study examined both qualitative and quantitative data and combined the results only in interpretation by adopting a convergent parallel design (Creswell & Plano Clark, 2011). Such integration made the results more valid and enabled the study to outline a more detailed representation of the potential impact of digital twin technology on the disposal process of property.

The combined analysis made it possible to have a stronger sense of the general findings (based on the tenant surveys) and of the insights that run deeper (based on the interviews with property managers). The two-sided views presented by both parties meant that conclusions that were made represented the realities in which the tenants lived as well as the realities carried out by the property managers, whether on grounds of their demographics and their previous exposure to digital technology or not.

■4.0 FINDINGS AND DISCUSSION

According to the study's findings, property management can undergo substantial changes as a result of digital twin technology. In the sections that follow, these findings are expanded upon, examined in the context of their results, and utilised to offer fresh perspectives gleaned from the research.

4.1 Reduction in Maintenance Costs

The substantial decrease in maintenance expenses that was noted in this study was a major advantage of using such digital twin technology. A substantial 30% reduction in property managers' expenses was made possible by the digital twin technology. Essentially, the primary driver of this decrease is the technology's ability to give property managers an early warning of potential issues before the bills become excessive.

Table 3 Maintenance costs before and after digital twin implementation

Category	Mean Cost Before (RM)	Mean Cost After (RM)	Reduction (%)	Standard Deviation
Maintenance Expenses	RM 100,000	RM 70,000	30%	RM 12,000

The financial benefits of using a digital twin are clearly displayed in Table 3. Therefore, the mean maintenance cost prior to the digital twin's introduction was RM 100,000; however, the mean cost after the digital twin was implemented was RM 70,000, a 30% decrease. It implies that maintenance costs vary (the standard deviation of RM 12,000 for maintenance costs) across various properties, as demonstrated by the steady decline in maintenance costs over a number of cases. It assists in anticipating maintenance requirements and planning repairs for off-peak times, minimising interruptions, prolonging equipment life, and eventually lowering maintenance expenses overall.

4.2 Decrease in Tenant Complaints

Tenant complaints decreased by 25% after digital twin technology was implemented, which was the study's other significant finding. Tenant satisfaction has significantly increased as a result of the prompt and better problem-solving. Instead of dealing with problems after they have grown into more significant and costly issues, property managers are able to address tenants' concerns in real time.

Table 4 Tenant complaints before and after digital twin implementation

Category	Before Implementation	After Implementation	Percentage Reduction	Total Complaints Considered
Number of Complaints Recorded	400	300	**25%**	600

Tenants believe that the digital twin lowers complaints, as indicated in Table 4. A high number of unresolved tenant issues is indicated by the fact that 400 of the 600 complaints that were taken into consideration were documented prior to the implementation of the digital twin. Following the implementation of digital twins for predictive maintenance, there were 300 recorded complaints, a 25% decrease. By facilitating proactive issue resolution and reducing disruptions before they worsen, digital twin technology has been shown to be effective in improving tenant satisfaction. Increased responsiveness brought about by digital twins has contributed to a better rental experience, which is crucial for retaining tenants and achieving a high occupancy rate.

4.3 Improved Tenant Satisfaction

In addition to lowering complaints, the enhanced living conditions and speedy problem solving made possible by digital twins increase the tenants' level of overall satisfaction. Technology has made it possible to customise services based on real-time data, giving tenants a more comfortable and customised living space.

Table 5 Tenant satisfaction levels before and after digital twin implementation

Category	Before Implementation	After Implementation	Percentage Increase
Tenant Satisfaction Score	70%	85%	15%

Tenant satisfaction increased by 15% as a result of digital twin technology, as Table 5 demonstrates. The significance of having a well-maintained and responsive living space for tenants who are vying for space and time in the competitive rental market is highlighted by this improvement.

4.4 Reduced Operational Costs

A 20% cost reduction was also recommended by the study, which was linked to improved resource management and reduced energy use. Everything from waste to efficiency can be decreased by allowing property managers to make decisions based on data and continuously monitoring building systems and occupancy patterns.

Table 6 Operational costs before and after digital twin implementation

Category	Before Implementation	After Implementation	Percentage Reduction
Total Operational Costs	RM 50,000	RM 40,000	20%

Table 6 illustrates how digital twin technology lowers operating costs and indicates that this is a possible cost reduction. Property minimisers will improve energy efficiency and cut waste for both property managers and individual tenants. Better resource allocation and energy efficiency are possible. The relationship between the adoption of digital twin technology and the effectiveness of property management is measured using a straightforward linear regression model. The findings are shown in Table 7.

Table 7 The relationship between the adoption of digital twin technology and the effectiveness of property management

Predictor	Coefficient (β)	Standard Error	t-Statistic	p-Value	R²
Intercept (β_0)	2.15	0.45	4.78	0.001	0.78
Digital Twin Technology Adoption (β_1)	0.65	0.12	5.42	0.000	

The adoption of digital twin technology can account for 78% of changes in property management efficiency, according to the R^2 value of 0.78. This implies that property management efficiency is increased by 6.5 percent for every 10% increase in the adoption of digital twins. This is assuming that $\beta_1 = 0.65$. The p-value (0.000) confirms that the relationship is statistically significant at a 95% confidence level. If the digital twin is implemented more widely, the property management can gain from increased operational efficiency, lower maintenance costs, and happier tenants.

4.5   Enhanced Predictive Maintenance

Predictive analytics and real-time monitoring are two industrial practices made possible by digital twin technology. As a result, property managers are no longer concerned about allowing issues to worsen to the point where extensive repairs are necessary. This forward-thinking approach extends the life of the building systems and reduces maintenance costs while also reducing downtime.

Table 8 Predictive maintenance results prior to and following the use of digital twins

Outcome	Before Implementation	After Implementation	Percentage Improvement	Unit of Measurement
Equipment Downtime	15%	5%	67%	% of total operational hours per year
Emergency Repair Incidents	10	3	70%	Number of repairs per month
Equipment Lifespan	8	12	50%	Years

Table 8 provides a comparison of predictive maintenance outcomes before and after the implementation of digital twin technology. The data shows a significant reduction in equipment downtime and emergency repair incidents, as well as a notable increase in equipment lifespan. These improvements are indicative of the long-term benefits of predictive maintenance in property management.

During the study, it was determined that digital twin innovation has a huge impact on property management decision-making. According to the experience of property managers, instantaneous data provided by digital twins, encompassing building systems, occupancy, and tenant behaviour, enable faster and more relevant decisions to be made (Pomè & Signorini, 2023). Such instant observation simplifies the work, enhances tenant experience and generates superior management results since decisions are made in close connection with real-life conditions. In addition, managers described that digital twins are critical to the development of sustainability goals. Energy and resource systems can be closely monitored and controlled in real-time, which minimises waste and operating expenses,

resulting in turning properties into environmentally friendly assets (Hodavand et al., 2023). These comprise ecologically apt and financial. The second significant takeaway is how versatile and expandable the digital twin technology is. According to the study, digital twins can be adjusted to fit any given property, either residential or commercial, small and large, and thus can be customised to suit a variety of management requirements (Biagini et al., 2024). This feature paves the way toward its wider use and implies revolutionary changes involving more intelligent and data-driven property management.

Digital twin applied in property management has become an essential source of data that will be extensively used in future projects but needs an enormous capital outlay on sensors, IoT products, and digital twin systems (Vieira et al., 2024). A key finding on the implementation of digital twins in property management is that it has become a launching pad of critical data that will be used in subsequent endeavours, but this comes with heavy capital investment (Vieira et al., 2024). With these costs being so high up front, property managers will need to do in-depth forecasting on ROI in order to justify the expense (Sandström & Berntsson, 2023). Furthermore, digital twin solutions can provide value only in case the management team is well trained to interpret the insights and take necessary actions, which demands constant investment in staff education and professional growth (Vieira et al., 2024).

The study also found out the need for smooth integration of new platforms of digital twins and current systems of properties. Almost 30 per cent of the surveyed property managers pointed out the importance of data integration in successful implementation (Vieira et al., 2024). To be deployed effectively, therefore, it must be compatible with legacy systems. The process of continuous technological updates was also considered essential: property managers should not only follow new forms of innovations but also regularly update systems and directly and constantly educate employees to remain competitive (Naeem et al., 2023). The second important strategy is active participation of the tenants in the process of adoption. A discussion on the benefits and the tenant buy-in helps increase trust and boost the progress towards faster transitions to digital twin systems (Sandström Berntsson, 2023). The study as a whole shows the transformational value of digital twins, namely, drastic cuts in maintenance and operation costs, increased satisfaction of tenants, and accurate maintenance predictions (Batty, 2018). This information is useful in the future implementation of digital twins in the real estate industry.

As property management continues to advance, digital twins—like all innovations—will become essential for staying ahead of the curve and meeting the needs of stakeholders and tenants. Predictive analytics and real-time data will therefore rule the future, improving sustainability and lowering the cost of property management operations. This study makes a case for the industry's widespread adoption of digital twin technology by demonstrating how revolutionary it can be.

4.6 Digital Twin Optimisation

In Malaysia, due to climatic and environmental conditions that are conducive to depreciation of building systems, digital twin technology's optimisation for predictive maintenance is even more advantageous. Malaysian weather has a significant impact on the lifespan and energy consumption of electric structures, HVAC (heating, ventilation, and air conditioning) systems, and building exteriors. High humidity and temperature swings exacerbate this, hastening wear and resulting in more frequent breakdowns and higher maintenance costs. The challenge presented by digital twin technology is the ability to monitor vital building systems in real time and identify possible problems before they become serious. In Kuala Lumpur, for instance, sensors in air conditioning systems in tall buildings transmit performance data to the digital twin system unless they are used to forecast trends and identify signs of deteriorating efficiency or a worn-out component. Consequently, a predictive maintenance approach reduces unplanned breakdowns, extends the life of building assets, and lowers overall maintenance expenses. In order to ensure sustainable property management in Malaysia through anticipatory maintenance strategies, digital twins are an essential tool because they allow for more economical and efficient operations.

Furthermore, tenant satisfaction is critical and is rapidly emerging as the next frontier of differentiation in Malaysia's rapidly growing real estate market, where digital twins are valuable assets in improving tenant satisfaction levels. This group of tenants is in the central business districts of Kuala Lumpur, Penang, Johor Bahru, and other cities where tenants demand more comfort, convenience, and competent management. They help property managers to satisfy such expectations through the provision of relevant services as well as quick responses to any problems. For example, a digital twin can analyse a situation when the cooling systems of a commercial building will probably fail during a working day of a particular week, and after receiving this signal, the management can perform maintenance during non-office hours, thus not inconveniencing office-going workers. In addition, its flexibility allows one to design an indoor environment to the preferences of the tenant, for example, to regulate lighting and air conditioning depending on occupancy. Such levels of services not only increase satisfaction among tenants but also sustain long-term tenancy, which is very essential for the sustenance of property-managing businesses.

This study's contribution focusses on how digital twin technology has revolutionised property management in terms of lowering operating costs and improving sustainability and energy efficiency. By providing real-time insights into building performance and energy consumption, digital twins assist property managers in optimising resource utilisation and thereby reducing costs. Large commercial complexes in Kuala Lumpur demonstrate how the incorporation of digital twin systems has improved tenant welfare, maintenance issues, and energy management. Through predictive maintenance and automated energy demand adjustments, digital twins also help Malaysia's efforts to mitigate climate change and lessen environmental impact. This research indicates that digital twin technology is a great way to change the commercial real estate sector in Malaysia in order to increase building operations' sustainability, efficiency, and cost effectiveness.

Admittedly, there is no denying that digital twin technology has several benefits and at the same time, its application is not without certain difficulties. Some of the issues that property management firms may face include the initial cost of investment in the right sensors, IoT devices, and the right data analytics platforms, which may not come cheap, especially to mid- and small-scale firms. In addition, for digital twin technology implementation to be successful, organisations need employees who possess adequate knowledge of data and digital instruments. Another concern for property managers is the fact that the application and interpretation of data from digital twins need to be managed; training programs are therefore required to assist teams to understand how to analyse the extensive amounts of data that are produced. In Malaysia in particular, which is an environment where the importance of digital skills is gradually being promoted, this test

represents a chance for improving an employee's skills in the real estate field. Besides that, the problem of data confidentiality and security should also be mentioned because the data collected within the framework of the use of digital twins can also be unsafe. As such, overcoming these barriers will require strong security in cyberspace programs and a willingness to keep on learning and improving.

■5.0 CONCLUSION

The concepts of digital twins, which are extremely intricate digital representations of real-world systems, processes, and objects, are predicted to completely transform Malaysia's real estate management sector. According to this study, there are numerous advantages to using digital twins, including predictive maintenance, reduced operating costs, and increased tenant satisfaction. These are not marginal improvements, but a way forward in how properties are run in order to optimised real estate operation to be more efficient, sustainable, and provide greater value to tenants. The adoption of digital twins is now inevitable in the premise of Malaysian real estate since the country is still in its urbanisation process and integrating the use of technology into its processes.

In general, the conclusions made from this study can provide the following contributions and suggestions for future research. Firstly, further research on the cost and benefits associated with implementing digital twin technology in the context of Malaysian real estate needs to be carried out in the long run. Future studies could, therefore, go further to evaluate the return on investment for such a system after installation over a much longer period, taking into account the savings in maintenance costs, energy bills, and tenancy rates. Second, research efforts could be devoted to investigating the use of the digital twin on a range of properties and property sizes, from tall office buildings to housing and shopping malls. It will be essential to learn how such adaptable specific technologies as digital twins can be tuned to address different situations. Thus, further exploratory research could focus on the possible ways for using the concept of digital twin in conjunction with other innovation trends like artificial intelligence and machine learning to improve the predictive capacity and effectiveness of employing solutions in property management.

All in all, digital twin technology provides an innovative solution in the management of real estate in Malaysia, and the case identified areas of great improvement such as predictive maintenance, better customer satisfaction, and fewer operations costs. With the improvement of urbanisation and the advancement to IT, digital twins have been becoming crucial for property managers who want to adapt to Malaysian contexts and fulfil its sustainable goals. Consequently, the data earlier discussed in this paper evidence that digital twins are not only a technological phenomenon of the modern era but a strategic instrument for the evolution of property management practices. In the next research, the concern for implementation and the identification of the potential of this technology would be the driving factors to gain the benefits that would be offered by digital twins to the real estate sector in Malaysia.

Conflicts of Interest

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

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