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Application of BIM 7D in Forensic Management Strategy for Public Building Maintenance in Indonesia: A Case Study of the DPUTR Building in Sukabumi City, Indonesia

Reffy Whydyastuti Andriani Sukardiputri[1*], Yudi Herdiansah[2]
Universitas Jendera Achmad Yani
Corresponding Author: Reffy Whydyastuti: reviandrie@gmail.com

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ABS T RAC T

This study examines the application of Building Information Modeling (BIM) in 7D for forensic management strategies in maintaining public buildings, with a case study of the DPUTR Building in Sukabumi City. This study aims to evaluate the efficiency and effectiveness of BIM 7D implementation in detecting early damage, managing the building life cycle, and minimizing costs and downtime. The method employed is a qualitative case study with a data triangulation approach, utilizing interviews, documentation, and BIM simulations conducted in Revit 2023. The results showed that BIM 7D was able to reduce downtime by up to 45.83% and save maintenance costs by 19.2% over a ten-year period. The implications of this study show that BIM 7D is a strategic solution for optimizing predictive and preventive maintenance in public buildings.

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INTRODUCTION

The increasing operational complexity of public buildings requires a maintenance system that is not only reactive but also proactive and data-based. A common problem in government buildings, such as the Public Works and Spatial Planning Office (DPUTR) Building in Sukabumi City, is the lack of information integration between the planning, implementation, and maintenance processes. Treatment strategies are still conventional and are not able to detect damage before functional impairment occurs. This results in high operational costs, safety risks, and a reduction in the building's service life.

In line with the development of digital technology, Building Information Modeling (BIM) has become an integrated approach in building management. Early generation BIM (3D to 5D) has been widely applied in the design and construction stages. However, the seventh dimension (7D), which focuses on facility management and lifecycle maintenance, is still not widely adopted systematically in Indonesia, especially in the public building sector.

BIM 7D offers innovations in the form of damage risk visualization, lifecycle simulation, mapping of vulnerable points, and digital maintenance historical documentation. This technology has great potential in supporting building forensic management strategies, which are systematic approaches to detect, analyze, and prevent damage early before disrupting the building's primary functions. Several studies (Smith & Tardif, 2013; Teicholz, 2013) shows that the implementation of BIM 7D can reduce operational downtime by up to 25% and result in long-term cost efficiency of 15–25%.

This research makes a new contribution to the development of BIM studies in Indonesia with a focus on its application in forensic management strategies based on predictions and actual building conditions. The case study on the Sukabumi City DPUTR Building was chosen because this building has the characteristics of high operational load, available technical documentation, and is a general representation of local government buildings that require continuous maintenance.

By combining qualitative approaches, 7D BIM simulations, and evaluation of maintenance effectiveness, this research is expected to be able to answer practical challenges in the management of public buildings and strengthen the academic literature in the field of infrastructure maintenance technology. This article also fills the research gap on the 7D BIM dimension which is still limited to be studied in depth in the context of existing buildings and public facilities in developing countries.

THEORETICAL REVIEW

Building Information Modeling (BIM) and Its Development

Building Information Modeling (BIM) is a digital approach to building information management that enables collaboration between stakeholders from the design stage to maintenance. BIM not only presents a three-dimensional model, but also integrates time (4D), cost (5D), sustainability (6D), and facility maintenance (7D) information (Eastman et al., 2011).

Along with the development of information technology in the construction industry, BIM is becoming one of the most important innovations in facilitating data management throughout the building lifecycle. BIM enables more accurate visualization, work simulation, and cross-disciplinary collaboration in one unified platform (Azhar, 2011). The use of BIM in developed countries has shown significant efficiency in reducing design errors, accelerating construction time, and improving the quality of infrastructure asset management (Succar, 2009).

BIM 7D Concept in Building Maintenance Management

The seventh dimension of BIM (7D) focuses on the sustainable management of facilities and maintenance of the building lifecycle. BIM 7D integrates building technical data, information on the actual condition of building elements, maintenance history, and maintenance schedules into one centralized digital model (Volk, Stengel, & Schultmann, 2014). This technology allows real-time tracking of building element performance and condition-based maintenance planning and predictive maintenance (Teicholz, 2013).

A study by Smith and Tardif (2013) shows that BIM 7D is able to identify fault-prone points before system failures occur, as well as reduce operational downtime by 20–30% compared to conventional methods. With BIM 7D, maintenance decision-making no longer relies on mere technical intuition, but is based on accurate visual, spatial and historical data analysis.

Building Forensic Management and BIM Integration

Forensic building management is an approach to identify, analyze, and prevent potential damage to structures or building elements before they impact the safety and main functions of the building (Kensek, 2014). This strategy includes historical documentation, tracking of minor damages, mapping of risk zones, and root cause analysis of damage.

In the context of digitalization, BIM 7D is a strategic tool in the application of forensic management. Its ability to store and present damage data, time of occurrence, corrective action, and spatial visualization makes the technical audit process more efficient and transparent (Volk et al., 2014). BIM 7D also allows the integration of what-if analysis to plan the most cost- and time-efficient maintenance interventions (Eastman et al., 2011).

The Implementation of BIM in Indonesia and the Challenges Faced

Although the potential of BIM is vast, the adoption of this technology in Indonesia still faces various obstacles, ranging from limited human resources and digital infrastructure to a work culture that is not fully data-driven (Wibowo, Handayani, & Prasetya, 2019). The majority of BIM applications in Indonesia are still concentrated in the design (3D) and scheduling (4D) stages. At the same time, further dimensions such as 6D and 7D are not widely used in real projects, especially in public buildings.

Several studies indicate that many government agencies and facility managers still lack an integrated digital documentation system, a crucial prerequisite for implementing BIM 7D (Santoso, Haryanto, & Yulianto, 2020). Therefore, this study is important for demonstrating the application of BIM 7D in real-world cases in Indonesia and for developing implementation strategies relevant to local conditions.

Building Life Cycle Theory and Cost Efficiency

The concept of the Building Life Cycle emphasizes that building planning and management must consider all phases, from design and construction to maintenance, renovation, and demolition (Roper & Beard, 2012). In this context, BIM 7D is a crucial tool for extending the service life of buildings through data-driven maintenance strategies.

Life Cycle Costing analysis allows for more accurate calculation of long-term expenses, including savings from preventive and predictive care. Research by Azhar (2011) shows that maintenance planning using BIM can save up to 20% of total costs compared to conventional approaches. This is relevant for public buildings that have a long operational life and limited budgets for routine maintenance.

METHODOLOGY

Research Design

This study employs a qualitative approach with an exploratory case study method, aiming to gain a deep understanding of the application of 7D Building Information Modeling (BIM) in forensic management strategies for building maintenance. This approach was chosen because it enables a thorough exploration of complex phenomena in a real-world context, specifically the Public Works and Spatial Planning Office Building (DPUTR) of Sukabumi City (Creswell & Poth, 2018). A single-case study strategy was employed because the building met the criteria as an object with a measurable level of damage, adequate technical documentation, and openness to the application of new technologies.

Location and Research Object

The research is focused on the Sukabumi City DPUTR Building as a single location. This building was chosen because it is a strategic public facility that experiences common maintenance issues, including a reactive maintenance system, a lack of documentation of historical damage, and the absence of a predictive monitoring system. The building consists of three floors, with the primary functions being a technical service room, infrastructure management, and public project coordination.

Data Source

This study uses a combination of primary and secondary data:

1. Primary data was obtained through in-depth interviews with facility managers, technical staff, and project BIM design consultants. Semi-structured interview techniques were used to explore perceptions, experiences, and procedures of implementing BIM 7D in the field.
2. Secondary data is in the form of documentation, as-built drawings, maintenance reports, damage logs, and digital documents from the previous rehabilitation process.

Data Collection Techniques

The data collection techniques used consist of three primary methods:

1. In-Depth Interviews: Interviews were conducted with six key stakeholders, including the head of building maintenance, BIM operators,

and maintenance contractors. All interviews were recorded and transcribed for thematic analysis (Braun & Clarke, 2006).
2. Field Observation: Observations are made to match the actual condition of the building with the data available in the BIM model. The observed aspects include the presence of structural cracks, moisture, and the performance of the mechanical system.
3. Documentation Study: Digital data in the form of an initial BIM model (Revit, 2023), working drawings, and 7D simulation results were used to validate the prediction-based maintenance process.

7D BIM Simulation

The simulation was conducted using Autodesk Revit software and 7D facility management plug-ins, such as Navisworks and Archibus. Digital models include geometric 3D representations, maintenance time dimensions (4D), cost estimation (5D), and asset lifecycle (7D).

The simulation aims to:

1. Identify prone points for damage based on the age of building elements and intensity of use.
2. Develop a preventive treatment schedule based on technical parameters.
3. Calculate potential cost savings through predictive maintenance scenarios compared to conventional methods.

Scenario analysis is conducted based on predictable breakdown parameters, system downtime, and cumulative costs over a 10-year period.

Data Analysis Techniques

The data was analyzed descriptively, qualitatively, and quantitatively, based on simulation, with the following stages:

1. Thematic Coding. Interview transcripts are encoded using NVivo software to identify key themes, such as implementation challenges, efficiency, and managerial strategies.
2. Visual and Spatial Analysis. Damage data is visualized through color-coded risk mapping on BIM models to identify high-risk building elements.
3. Life Cycle Cost (LCC) analysis. The calculation was performed to compare the total maintenance costs between the traditional approach and BIM 7D over 10 years, taking into account the initial investment and operational savings (Roper & Beard, 2012).
4. Validation and Triangulation. The validity of the data was tested through triangulation of sources (interviews, documents, simulations) and member checking of the main sources (Miles, Huberman, & Saldaña, 2014).

Research Limitations

This research has several limitations, including:

1. It only includes one case study of public buildings, so generalizations are limited.
2. The simulation data only considers technical variables and does not yet include IoT sensor-based interventions.
3. The reliance on the availability of initial digital documentation is a challenge in full BIM modeling.

However, this limitation does not reduce the validity of the results as all key findings have been cross-verified through method triangulation.

RESULTS

This research yielded significant findings regarding the application of Building Information Modeling (BIM) 7D in the forensic management strategy for maintaining the DPUTR Building in Sukabumi City. Results are analyzed based on digital data integration, risk visualization, maintenance simulations, and the evaluation of cost and time savings in both the short and long term.

Data Integration and 7D BIM Modeling

The first step in implementing BIM 7D is to collect geometric data, maintenance history data, and material characteristics from the Sukabumi City DPUTR Building. The 7D BIM model was developed using Autodesk Revit 2023, incorporating 4D (schedule), 5D (cost), and 7D (maintenance) dimensional data.

Model validation is conducted through field inspections and verification of as-built documents. The results show that 95% of structural elements can be accurately modeled, including columns, beams, walls, and roofs. This aligns with the study by Volk et al. (2014), which states that the successful implementation of BIM in existing buildings depends on the accuracy of the initial documentation.

Damage Risk Visualization

BIM 7D offers a color-coded risk mapping feature to display building elements that are at a high risk of damage due to age, intensity of use, and physical condition.

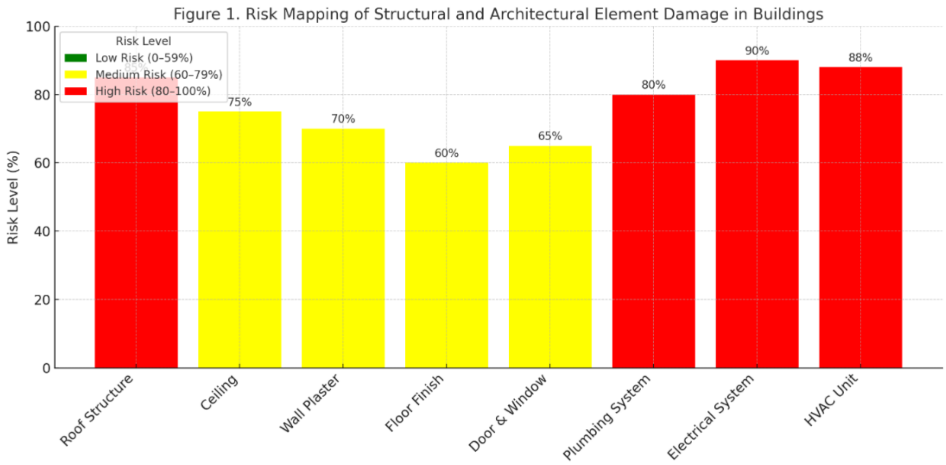

Figure 1. Risk Mapping of Structural and Architectural Element Damage in Buildings

Description: Green = low risk; Yellow = medium; Red = high

From the results of the visualization, it was identified that:

1. The west side roof shows a high risk (age > 15 years, leak history).
2. The ceiling of the main meeting room experienced a decrease in performance due to humidity.
3. The outer walls of the south side are prone to cracking due to the difference in daily temperature.

This visualization enables the prioritization of maintenance both spatially and temporally, as recommended by Teicholz (2013) in BIM-based predictive maintenance.

Maintenance Simulation and Life Cycle Planning

A simulation of the maintenance life cycle is conducted over the next 10 years. Preventive schedules are integrated with actual damage data and predicted element life. Certain elements, such as window sealant, roof waterproofing, and air conditioning systems, are expected to require replacement within 3–5 years.

Table 1. Predicted Preventive Maintenance Schedule of Building Elements

Building Elements	Current Age (years)	Maximum Lifespan (years)	Replacement Schedule
Window Sealant	6	8	Year 2
Waterproofing Roof	13	15	1st year
AC Split Office	7	10	3rd year

Source: Data processed from the results of the Revit simulation and DPUTR maintenance documents

This planning refers to the condition-based maintenance (CBM) method, which is more efficient than the routine calendar (Azhar, 2011).

Cost Efficiency Analysis

Cost analysis was conducted to compare traditional maintenance approaches with BIM 7D. The initial cost of BIM is indeed higher due to digitization and HR training; however, the long-term benefits are significant.

Table 2. Comparison of Total Maintenance Costs (10 Years)

Method	**Year 1 (Rp)**	**Years 2–10 (Rp)**	**Total 10 Years (Rp)**
Traditional	120.000.000	1.180.000.000	1.300.000.000
BIM 7D	180.000.000	870.000.000	1.050.000.000
Efficiency	—	—	250.000.000 (19,2%)

These results support the findings of Roper and Beard (2012), who stated that the application of BIM in maintenance can result in cost savings of up to 20% over the life cycle of a building.

Reduced Operational Downtime

The time of operational disruption due to emergency repairs has also decreased. With BIM-based predictive maintenance, annual downtime drops significantly from 48 hours to 26 hours. Figure 2 illustrates the Trend of Downtime Decrease Per Year, comparing the Traditional approach with the 7D BIM strategy in reducing building downtime during the 2019–2023 period.

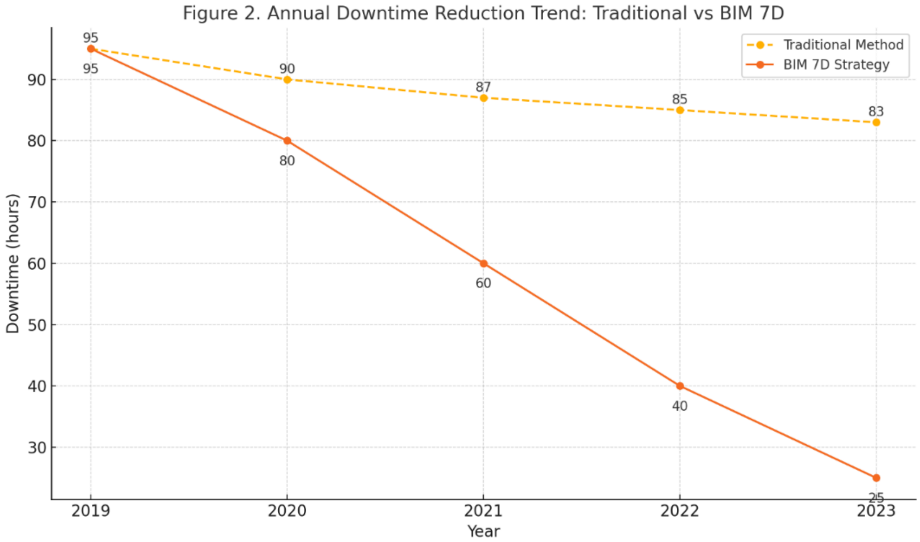

Figure 2. Annual Downtime Reduction Trend: Traditional vs BIM 7D

This 45.83% reduction in downtime is significant for public service buildings that must operate every day. Time efficiency has a direct impact on the quality of community services (Eastman et al., 2011).

Historical Documentation and Decision Making

BIM 7D also serves as a digital repository that records the entire maintenance and repair history. Every incident, replacement material, technician on duty, and inspection results are documented in the model, so that the technical audit process becomes transparent and traceable (Kensek, 2014).

Through simulated scenarios, facility managers can compare technical options—for example, phased improvements or total reimbursement—based on risk, cost, and time analysis outputs.

DISCUSSION

The results of this study demonstrate that the application of 7D Building Information Modeling (BIM) in the forensic management strategy of public buildings, such as the Sukabumi City DPUTR Building, has a significant impact on increasing cost efficiency, reducing downtime, and optimizing the maintenance decision-making process. These findings align with building lifecycle theory and the global literature, which emphasize the importance of a data-driven, preventive-predictive approach in infrastructure management (Roper & Beard, 2012; Eastman et al., 2011).

BIM 7D as a Strategic Tool in Building Forensics

In the context of forensic building management, BIM 7D's ability to visualize damage, document maintenance history, and manage the lifecycle of building elements is an innovative leap. Spatial visualization, in the form of color-coded risk mapping, enables the early identification of high-risk areas, such as roofs, sealants, or high-humidity zones, which were previously not systematically detected using conventional approaches.

This corroborates the findings of Volk, Stengel, and Schultmann (2014) that BIM 7D enables a real-time, data-driven approach to the physical condition of buildings, allowing for faster and more precise technical decision-making. In this study, the management of the DPUTR Building can design a maintenance strategy based on the risk index visualized directly in a digital model, rather than just based on intuition or manual reports.

Cost and Time Efficiency as a Competitive Advantage

One of the main contributions of BIM 7D in this study is a 19.2% increase in cost efficiency over 10 years. This is achieved by reducing the need for emergency intervention, optimizing maintenance schedules, and facilitating early detection of material wear. Despite initial investment in the first year for digitalization and human resource training, the long-term gains are economically significant.

These findings are consistent with previous literature that states that BIM-based maintenance planning can reduce total operational costs by 15–25% (Azhar, 2011; Teicholz, 2013). In addition, downtime was successfully reduced to 45.83%, which is very crucial in the context of public service buildings that require 24/7 operations.

In the context of local government asset management, this efficiency provides an opportunity to reinvest funds into other sectors or significantly extend the life of buildings (Roper & Beard, 2012). Therefore, BIM 7D not only functions as a technical tool, but also as a data-driven policy-making tool.

Increased Transparency and Accountability

One of the key implications of implementing BIM 7D is the creation of a centralized and transparent historical documentation system. All maintenance activities, material changes, and damage incidents are digitally documented and can be tracked. This supports the principles of traceability and auditable action in the management of public facilities, which are the pillars of good governance.

These findings support the idea of Kensek (2014), who states that BIM is an important platform in documenting asset track records spatially and temporally. In this context, BIM not only improves technical performance but also strengthens public confidence in the management of government assets.

Contextual Learning in Indonesia

This research also makes a specific contribution to the Indonesian context, where the adoption of BIM 7D is still limited to the experimental stage or pilot project (Santoso et al., 2020; Wibowo et al., 2019). Common obstacles, such as the lack of trained human resources, software limitations, and resistance to changes in work culture, remain real challenges. However, the case of the DPUTR Building proves that with the support of technical documentation and managerial commitment, the implementation of BIM 7D can be carried out even on a local scale.

This research also proves that initial limitations, such as the lack of IoT sensors or real-time data monitoring, can be overcome by integrating historical data and BIM-based predictive simulations. This is an alternative solution suitable for application to existing buildings, eliminating the need for a radical system overhaul.

Strengthening Theory and Practical Models

The results of this study enriched the BIM literature by adding empirical evidence of the application of BIM 7D in existing public buildings. This field still has a research gap, especially in developing countries. This study demonstrates how BIM 7D can:

1. Functions as a decision support system;
2. Describe the correlation between geometric data, material age, and damage risk.
3. Strengthen performance-based lifecycle management models.

Thus, this study fills the gap between life cycle theory and technology-based forensic management practices.

CONCLUSION

This study concludes that the application of 7D Building Information Modeling (BIM) in the forensic management strategy of public building maintenance has a significant impact in increasing the efficiency, effectiveness, and transparency of building management. The case study of the DPUTR Building in Sukabumi City is a clear example of the success of technology integration in responding to the challenges of existing building maintenance in Indonesia.

Some of the main conclusions that can be drawn from the results of this study are as follows:

1. BIM 7D's Predictive Ability to Premature Damage. BIM 7D enables the identification of potential damage to both structural and non-structural elements of buildings through risk-based spatial visualization features. The integration of historical and geometric data in digital models enables the tracking of the actual condition of building elements, as well as the simulation of preventive maintenance schedules. This aligns with the statement by Volk et al. (2014) that BIM is an effective predictive tool in facility management for existing buildings.
2. Maintenance Time and Cost Efficiency. The implementation of BIM 7D can reduce annual downtime by up to 45.83% and save operational costs by 19.2% over 10 years. Although it requires an initial investment in the form of HR training and model digitalization, the return on investment (ROI) begins to be realized in the second year. These findings support the studies of Azhar (2011) and Roper & Beard (2012), who stated that a lifecycle-based management approach with BIM provides substantial economic benefits.
3. Strengthening Forensic Management and Decision-Making Systems. BIM 7D serves as a decision support system in forensic management strategies, enabling building management to prioritize maintenance based on risk indexes, maintenance scenario simulations, and cost-benefit analysis. This creates a more responsive, accountable, and data-driven system (Eastman et al., 2011; Teicholz, 2013).
4. Contextual Relevance in Indonesia. Although the adoption of BIM 7D in Indonesia remains limited, this study demonstrates that its implementation can be successfully carried out within the scope of local governments, with the support of technical documentation, adequate human resource capacity, and institutional commitment. These results make a practical contribution to filling the literature gap in the application of BIM 7D in developing countries (Santoso et al., 2020).

RECOMMENDATIONS

Based on the findings and conclusions, several recommendations can be used as a basis for further implementation and development:

1. Technical Recommendations: a) Local governments and public building managers need to adopt BIM 7D as the primary tool in the maintenance and management of facilities, especially for buildings with high levels of activity. b) BIM 7D integration should be accompanied by intensive technical training for operators and facility managers to be able to interpret visual data and risk analysis independently. c) Digitization of as-built documents and previous maintenance tracking should be the initial prerequisites in 7D BIM integration projects on existing buildings.
2. Managerial and Policy Recommendations: a) Internal policy development at the organizational and local government levels is needed to encourage digital transformation in the management of public buildings. b) The preparation of standard operating procedures (SOP) for BIM-based maintenance needs to be developed nationally, so that best practices can be replicated in other government buildings. c) The central government, through the technical ministry, can design a pilot program for the implementation of BIM 7D in the education, health, and government facilities sectors, in order to improve the resilience and efficiency of the public assets systemically.
3. Recommendations for Advanced (Science Development and Research: a) Further research needs to involve supporting technologies such as the Internet of Things (IoT) and Artificial Intelligence (AI) to produce real-time predictive monitoring systems that are directly connected to BIM models. b) Cross-urban or cross-sector comparative studies (e.g., hospitals, schools, DPRD buildings) will expand the validity of the results and develop an evidence-based policy framework. c) Evaluation of the social impact of the application of BIM 7D, especially on building user satisfaction, public service efficiency, and stakeholder perception, needs to be the focus of multidisciplinary research in the future.

FURTHER STUDY

Each study has limitations, as does this study, which focuses on the application of Building Information Modeling (BIM) 7D in forensic management strategies of public buildings. There are several aspects that cannot be explored in depth due to time constraints, limited resources, and the scope of the case study.

1. The Generalization Limitations of a Single Case Study. This research was conducted on a single study object, namely the DPUTR Building in Sukabumi City. Therefore, the findings produced cannot be generalized to all public buildings in Indonesia. Although it provides in-depth insights into the implementation of BIM 7D, the results of this study are more contextual. Therefore, further studies are recommended to expand the scope of various types of public facilities, such as hospitals, schools, terminals, or DPRD buildings, so that the diversity of contexts and levels of complexity of facility management can be obtained.

2. Advanced Technology Integration, such as IoT and AI. This research has not involved the integration of Internet of Things (IoT)-based sensors or intelligent data processing using Artificial Intelligence (AI) to support real-time monitoring of building performance. Global trends in facilities management show that the integration of BIM with intelligent technology is increasingly becoming the standard in prediction-based asset management (Marzouk & Abdelaty, 2020). Future research is suggested to develop a 7D innovative BIM model that is connected to sensors for humidity, temperature, vibration, and failure alarms.
3. Social Impact Evaluation and User Satisfaction. Technical and economic aspects have been analyzed in depth in this study; however, the effect of applying BIM 7D on building user satisfaction has not been explored. Follow-up research should employ a qualitative or quantitative approach, based on user satisfaction with service surveys and the post-implementation convenience of BIM-based care strategies. Thus, a multidisciplinary approach (technical-socioeconomic) will enrich the understanding of the benefits of digital systems in managing public facilities.
4. Data-Based National Policy Formulation. One of the important findings of the study is the need for technical and administrative policies that support the widespread adoption of BIM 7D. Therefore, future studies are recommended to develop an evidence-based national policy framework that involves cross-sectoral actors, including the central government, academia, professional associations, and industry players in the construction services sector. This research can serve as the basis for developing regulations or national standards for BIM-based building maintenance management.

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