The Role of Technology to Sustainability in Building Maintenance for Infrastructure

Wiwik Wiharti[1]*

1 Sebelas Maret University, Surakarta, Indonesia

*E-mail: wiwikwiharti1@gmail.com

ABSTRACT

Based on the law No. 28 of 2002, The building is the outcome of construction activities that are either partially or entirely integrated into its location, whether on land or in water. In accordance with the definition of a building, the building must be able to be used for its intended function. In addition, all buildings have a service life. To achieve the planned service life, buildings must be maintained.

Building Information Modeling (BIM) is a building modeling process that was primarily based on 3D models and has been developed to 8D that provides information and tools that help the planning process to maintain assets more efficiently and effectively. BIM in its early days served to assist in the design, construction and operation of buildings. Although it has not been widely done, it is currently starting to develop BIM functions to assist building asset management. This article uses descriptive methods to describe the relationship between BIM technology and building maintenance for the implementation of sustainable building strategies. With this information, it is hoped that it can increase knowledge related to technology development for infrastructure which is very useful for easier maintenance on building assets and all data can be well organized. As well as the importance of the sustainable development strategy implementation.

KEYWORDS :

BIM; Building; Maintenance; Sustainable

1. INTRODUCTION

According to Indonesian Building, The building is the outcome of construction activities that are either partially or entirely integrated into its location, whether on land or in water. (Republik Indonesia, 2002). In accordance with the definition of a building, the building must be able to be used for its intended function. In addition, all buildings have a service life. To achieve the planned service life, buildings must be maintained.

The operation and maintenance of buildings in service have been ongoing for over 40 years(Jiao et al., 2023). The notions of “operation” and “maintenance” first appeared in 1976(Raouf & Kettunen, 1978). Building maintenance is essential for preserving an asset’s value. It ensures that building systems operate efficiently, extends equipment lifespan, and maintains a comfortable environment while managing operations in a cost-effective manner. (Shi et al., 2020) describes a comparable framework that allows grouping preventive maintenance tasks for different systems based on expected reliability and a specified minimum reliability level. Both emphasize minimizing maintenance costs in their respective publications(Meissner et al., 2021).

Maintenance is generally categorized as either preventive or corrective. Preventive maintenance focuses on routine maintenance schedules, while corrective maintenance addresses reactive measures in response to failures or breakdowns. In current practice, information needed for preventive maintenance can be more readily prepared in advance compared to the information needed for corrective maintenance(Motawa & Almarshad, 2013). A major challenge in projects is ensuring that sufficient product information is readily accessible for any maintenance tasks, including specifications, records of previous maintenance, and lists of specialized professionals for the job. Since building maintenance (BM) spans the longest phase of a building's life and involves multiple stakeholders who may change over time, it is essential for authorities and clients to keep detailed records of the products in use (Nummelin et al., 2011) To improve maintenance management performance, the Building Information Modeling (BIM) approach is implemented and developed into 3D information models for overseeing and maintaining facilities in the study. By integrating the BIM model with relevant maintenance information, facility maintainers can enhance the efficiency of both maintenance and management tasks(Su et al., 2011).

The United Nations has established 17 Sustainable Development Goals, which pose significant challenges not only to governments but also to a broad range of stakeholders. The importance of sustainable buildings in achieving the UN’s Sustainable Development Goals is emphasized through Goal 11, which focuses on Sustainable Cities and Communities (Marzouk et al., 2018). Sustainable development can be represented by a Venn diagram **(Figure 1),** with its three pillars being economic, social, and environmental. This diagram illustrates all possible logical relationships among these three pillars. Sustainability entails a responsible approach that reduces negative environmental impacts while maintaining a balance between these pillars. From this diagram, four domains of sustainable development are identified: ecological, economic, political, and cultural. Additionally, social and economic factors must be regulated by environmental considerations.

This article will explore how technology, specifically Building Information Modeling (BIM), contributes to sustainable building strategies and facilitates more efficient and effective maintenance.

Figure 1. Three pillars of sustainable development
Source :(Royer, 2019)

2. METHODOLOGY

This research purposes to describe the utilization of technology, specifically BIM, in an effort to implement a sustainable building strategy. In addition, from various related literature studies, it can be explained the role of BIM for sustainable infrastructure, maintenance on building components from the construction design stage to operation and maintenance. he data will be collected through a literature review related to BIM technology and its connection to sustainable building strategies. The study will review journals, scientific articles, reports, and other relevant sources to identify the role of BIM in sustainable infrastructure.

3.1 RESULTS AND DISCUSSION

3.2 BIM (Building Information Modelling)

Building Information Modeling (BIM) is revolutionizing the traditional methods of building delivery. The construction industry is expanding rapidly, and there is a growing demand for sustainable facilities that have minimal environmental impact. Sustainable development is categorized into areas such as water conservation, energy reduction, sustainable material procurement, industrial growth, recycling, waste minimization, climate change, transportation strategies, and biodiversity(Khan & Ghadg, 2019).

A crucial step in the planning process is to clearly define the potential benefits of BIM for the project and its team members by outlining the overall goals for its implementation. These objectives may focus on project outcomes and could include factors such as shortening the schedule, enhancing performance, improving quality, lowering change costs, or acquiring essential operational data for the facility (Videika & Migilinskas, 2020). IM is developed using object-oriented software. The most commonly used software includes REVIT, ARCHICAD, and BENTLEY. These programs operate with smart objects to create building components. These objects, which can be geometric or non-geometric, contain functional, semantic, or topological information (Kalfa, 2018). Through BIM systems, 3D models for architectural, structural, mechanical, electrical, and plumbing designs can be created. Additionally, for time planning, construction simulation, and cost analysis, 4D and 5D models are generated (Hardin & McCool, 2015). The dimensions of BIM are shown in **Figure 2**(Darko et al., 2020).

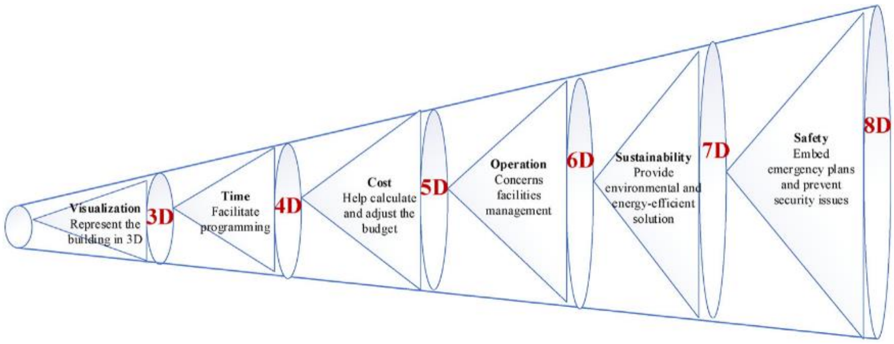

Figure 2. BIM Dimensions
Source : (Darko et al., 2020)

3.3 Process of Sustainable Building Operation and Maintenance Based on BIM

The selection of building techniques, components, and materials is typically based on factors such as functionality, technical performance, architectural aesthetics, cost, durability, and maintenance needs. However, this decision often overlooks the environmental and human health impacts. Sustainable building practices ensure that social, economic, and environmental factors are considered throughout the building's life cycle starting from the extraction of raw materials, through design, construction, usage, maintenance, renovation, and eventual demolition(Krawczyk et al., 2022). The process of sustainable building operation and maintenance is crucial to maximizing the life cycle and environmental benefits of modern buildings. BIM plays a transformative role in achieving sustainability objectives by enhancing efficiency and reducing resource consumption in building operations.

BIM is a collaborative digital model that represents the physical and functional properties of built assets, aiming to streamline design, construction, and operational processes for more informed decision-making. In Facility Management, BIM encompasses a comprehensive information repository, essentially a Big Data database, that serves as a building owner's manual. It offers valuable resources for analysis, supports emergency response, enhances security management, and facilitates scenario planning. As shown in **Figure 3** (Charef, 2022), There are various scenarios, including the application of BIM across the entire lifespan of the building.

Using BIM, facility managers and building operators can track real-time performance data, predict maintenance needs, and implement proactive measures to reduce energy use and minimize waste. This approach promotes a more sustainable building operation by optimizing resource utilization, reducing operational costs, and extending the building's lifespan. Additionally, BIM enables collaborative workflows among stakeholders, making it easier to address issues related to sustainability and compliance with environmental regulations.

Overall, adopting a BIM-based approach in the operation and maintenance of buildings is a step toward more sustainable and resilient infrastructure, aligning with the growing demand for environmentally responsible and energy-efficient practices in the built environment.

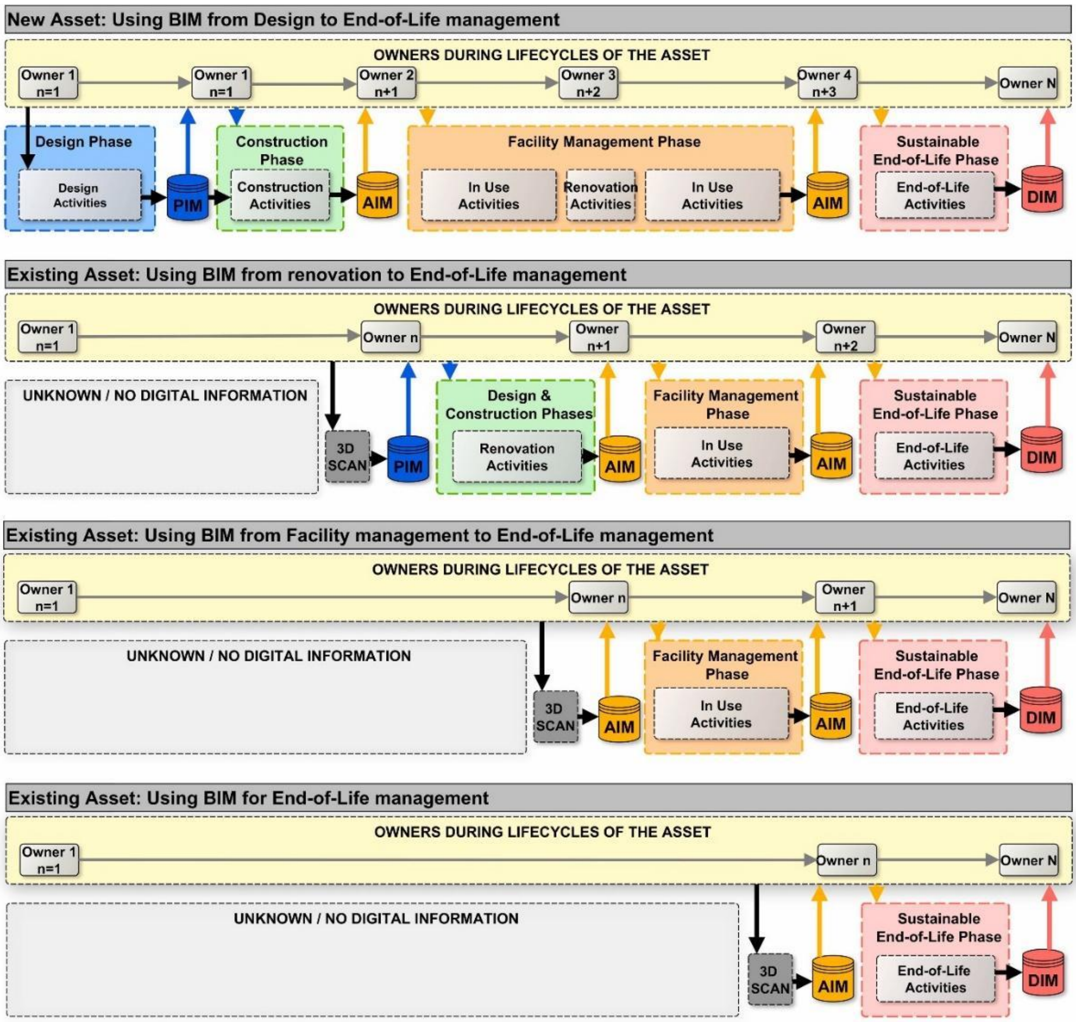

Figure 3. Various scenarios for the use of BIM throughout the asset lifecycle
Source : (Charef, 2022)

Facility personnel only need to connect the facility's maintenance documents to the relevant models once maintenance work is finished. Then, the facility manager or staff can easily access the information and maintenance documents using this external program. With the help of this program, users can gain a more thorough understanding of the facility's details and enhance the completeness of BIM implementation in facility management.

Each facility in a building is considered an individual entity with two types of properties: attributes and portfolios. Six types of basic equipment, such as HVAC, plumbing, and electrical systems, are represented as entities in BIM. Each entity has its own attributes (such as vendor information and location details) and associated documents (such as specifications, warranties, and manuals)(Wang et al., 2013). Product serial numbers specified by vendors will be gathered as unique identifiers for each facility. Model and part numbers serve as reference information during maintenance activities. Location details include the building number, floor, and room number, while the description provides the facility's current status. Attributes encompass weight, power, and energy consumption. This information is compiled into a standardized BIM database for seamless integration, interoperability needs to be assured, the illustration of the proposed structure the proposed BIM database for FM is shown in **Figure 4**(Wang et al., 2013).

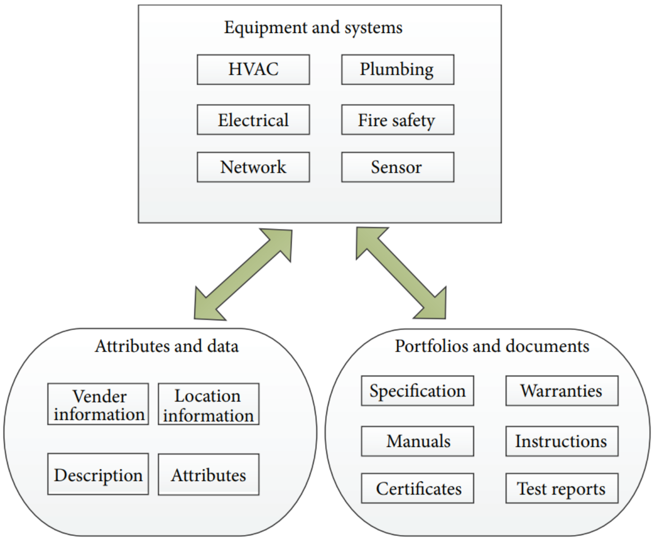

Figure 4. FM based BIM Database
Source : (Wang et al., 2013)

Furthermore, FM personnel can access relevant task data directly from BIM's graphical interface in real-time. For instance, when fixing a printer, they need to review the maintenance history, obtain the maintenance manual, create maintenance reports, and finalize the request. Traditionally, this would require logging into various electronic document management systems (EDMSs) and switching between multiple databases to gather all necessary information(Wang et al., 2013). Moreover, Building Information Modeling (BIM), as a virtual design and construction, is a communication tool for stakeholders. Besides, BIM is an effective strategy to minimize conflicts, misunderstandings and reduce uncertainties in the implementation and maintenance stages, in addition, BIM can visualize delay analysis for problem solving in the implementation and maintenance process in buildings.

Preventive maintenance (PM), also known as planned maintenance, involves preparing to perform maintenance tasks within the scheduled timeframe, which can help reduce the likelihood of accidents and failures to some extent (Dong et al., 2023). A schedule will be created for regular inspections. A detailed work description is recommended to enhance overall productivity, including the work order ID, facility ID, location, description of the preventive tasks, documents needed for maintenance, estimated and actual labor hours, and the frequency of maintenance activities (Wang et al., 2013). All of this data can be integrated into the BIM database as attributes and documents. By assigning a unique ID to each facility, a corresponding barcode can be provided to facilitate easy access to relevant information in real time via mobile devices. Furthermore, after each maintenance session, status updates and work hours will be sent back to the BIM system as feedback and reference for future tasks.

Figure 5. illustrates the workflow of BIM-based preventive maintenance (PM). By pre-designing maintenance details such as location information, relevant maintenance history, and PM schedules within BIM, the integrated data can be accessed efficiently. This ensures that future maintenance is well-planned and helps avoid unnecessary redesign (Wang et al., 2013).

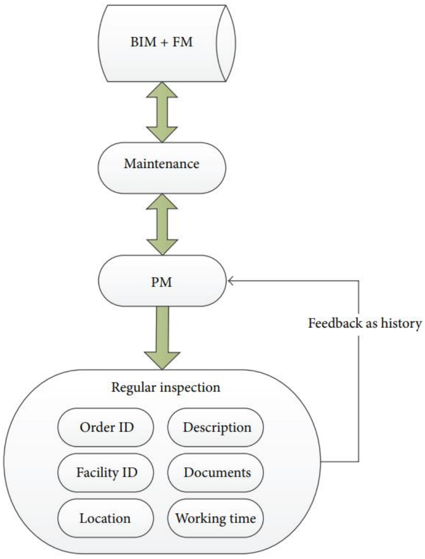

Figure 5. BIM-based Preventive Maintenance workflow
Source : (Wang et al., 2013)

By understanding the asset, the type of damage, and its maintenance requirements, an optimal maintenance interval can be determined. This is the preventive maintenance (PM) interval that minimizes maintenance costs throughout the asset's lifecycle for a specific PM task. A similar cost concept is illustrated in **Figure 6**, which demonstrates that extending the equipment's lifecycle through regular preventive maintenance can lead to substantial savings in operational and maintenance costs. In turn, preserving the building's service life aligns with the implementation of a sustainable building strategy.

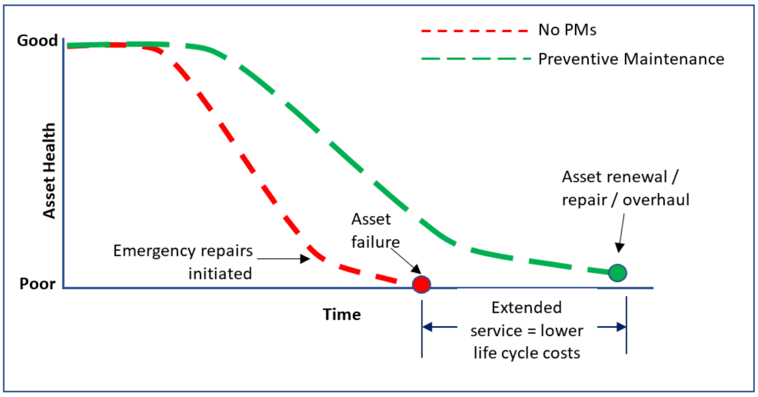

Figure 6. Relationship between Maintenance and Repair Costs
Source : (Borley, 2020)

3. CONCLUSION

BIM, as a repository for building assets and components, helps in managing the upkeep and maintenance of building elements, such as architectural, structural, utility, fire protection, accessibility, and environmental components, as well as building planning. Furthermore, through preventive maintenance, it can reduce associated costs. Continuous maintenance will ensure the building's longevity in line with the planned schedule. Therefore, utilizing BIM technology is an effective strategy for achieving sustainable buildings.

REFERENCES

Borley, J. (2020). *What is Preventive Maintenance?* Https://Www.Dynaway.Com/

Charef, R. (2022). The use of Building Information Modelling in the circular economy context: Several models and a new dimension of BIM (8D). *Cleaner Engineering and Technology*, *7*, 100414. https://doi.org/https://doi.org/10.1016/j.clet.2022.100414

Darko, A., Chan, A. P. C., Yang, Y., & Tetteh, M. O. (2020). Building information modeling (BIM)-based modular integrated construction risk management – Critical survey and future needs. In *Computers in Industry* (Vol. 123). Elsevier B.V. https://doi.org/10.1016/j.compind.2020.103327

Dong, L., Xiao, Q., Jia, Y., & Fang, T. (2023). Review of research on intelligent diagnosis of oil transfer pump malfunction. *Petroleum*, *9*(2), 135–142. https://doi.org/https://doi.org/10.1016/j.petlm.2022.01.002

Hardin, B., & McCool, D. (2015). *BIM and Construction Management : Proven Tools, Methods and Workflows* (Indiana, Ed.; Second Edition). Wiley & Sons.

Jiao, Z., Du, X., Liu, Z., Liu, L., Sun, Z., & Shi, G. (2023). Sustainable Operation and Maintenance Modeling and Application of Building Infrastructures Combined with Digital Twin Framework. *Sensors*, *23*(9). https://doi.org/10.3390/s23094182

Kalfa, S. M. (2018). Building information modeling (BIM) systems and their applications in Turkey. *Journal of Construction Engineering, Management & Innovation*, *1*(1), 55–66. https://doi.org/10.31462/jcemi.2018.01055066

Khan, A., & Ghadg, A. N. (2019). Building Information Modelling (BIM) based Sustainability analysis for a construction project. *Proceedings of Sustainable Infrastructure Development & Management (SIDM)*. https://ssrn.com/abstract=3366799

Krawczyk, D., Ruiz de Adana, M., Moreno-Pérez, M. F., Bullejos Marín, D., Teleszewski, T., & Teilans, A. (2022). *Sustainable buildings. Designing and management of cost-effective and eco-friendly systems*. https://doi.org/10.24427/978-83-67185-29-5

Marzouk, M., Azab, S., & Metawie, M. (2018). BIM-based approach for optimizing life cycle costs of sustainable buildings. *Journal of Cleaner Production*, *188*, 217–226. https://doi.org/10.1016/j.jclepro.2018.03.280

Meissner, R., Rahn, A., & Wicke, K. (2021). Developing prescriptive maintenance strategies in the aviation industry based on a discrete-event simulation framework for post-prognostics decision making. *Reliability Engineering and System Safety*, *214*. https://doi.org/10.1016/j.ress.2021.107812

Motawa, I., & Almarshad, A. (2013). A knowledge-based BIM system for building maintenance. *Automation in Construction*, *29*, 173–182. https://doi.org/10.1016/j.autcon.2012.09.008

Nummelin, J., Sulankivi, K., Kiviniemi, M., & Koppinen, T. (2011). *Managing Building Information And Client Requirements In Construction Supply Chain - Constructor's View*. https://api.semanticscholar.org/CorpusID:55392943

Raouf, A., & Kettunen, O. V. (1978). Developing Apartment Maintenance Systems As Urban Operations. *Kybernetes*, *7*(2), 131–140. https://doi.org/10.1108/eb005477

Royer, P. (2019). *Circular Economy, utopia or promising new business model? An evaluation of Circular Economy efficiency against environmental challenges*.

Shi, Y., Zhu, W., Xiang, Y., & Feng, Q. (2020). Condition-based maintenance optimization for multi-component systems subject to a system reliability requirement. *Reliability Engineering and System Safety*, *202*. https://doi.org/10.1016/j.ress.2020.107042

Su, Y. C., Lee, Y. C., & Lin, Y. C. (2011). Enhancing maintenance management using building information modeling in facilities management. *Proceedings of the 28th*

International Symposium on Automation and Robotics in Construction, ISARC 2011, 752–757. https://doi.org/10.22260/isarc2011/0140

Republik Indonesia. (2002). *Undang-Undang Republik Indonesia Nomor 28 Tahun 2002 tentang Bangunan Gedung*. Lembaran Negara Republik Indonesia Tahun 2002 Nomor 134

Videika, G., & Migilinskas, D. (2020). Evaluation Of The Main Standards For Sustainable Buildings And Evaluation Bim Details In The Commercial Project. *Mokslas - Lietuvos Ateitis*, *12*(0), 1–6. https://doi.org/10.3846/mla.2020.11379

Wang, Y., Wang, X., Wang, J., Yung, P., & Jun, G. (2013). Engagement of Facilities Management in Design Stage through BIM: Framework and a Case Study. *Advances in Civil Engineering*, *2013*(1), 189105. https://doi.org/https://doi.org/10.1155/2013/189105