

A Review of BIM Implementation in Indonesia's Smart Cities: Challenges and Opportunities

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Abstract

Indonesia's rapid urbanization poses critical challenges to city development and infrastructure management. In response, the government has promoted Smart City initiatives to leverage technology for more sustainable and efficient urban systems. Building Information Modeling (BIM) plays a promising role in supporting these initiatives, particularly in planning, collaboration, and data-driven decision-making. Yet, BIM adoption in Indonesia's Smart City efforts remains limited due to regulatory, technical, and institutional barriers. This paper reviews current practices, identifies key challenges, and explores opportunities for BIM integration in Indonesian urban development. Through a narrative literature review, the study highlights practical recommendations such as enhancing government-led regulations, capacity building, and cross-sector collaboration. These findings contribute to understanding how BIM can advance Smart City development not only in Indonesia but across similar contexts in the Global South.

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INTRODUCTION

Urbanization is a process of increasing urban population due to rural-to-urban migration. This migration is often driven by disparities in facilities between rural and urban areas, making urban regions attractive for individuals seeking job opportunities and improved living conditions (Harahap, 2013). The rapid urbanization trend across various Indonesian cities has created significant challenges in urban management and development. According to BAPPENAS (2018), Indonesia's population is projected to grow by 24.7% to 318 million by 2045, with urban populations increasing from 53.1% in 2015 to 67.1% in 2050. This urbanization trend exerts pressure on city infrastructure and services, resulting in increased congestion, environmental degradation, loss of green spaces, economic disparity, and higher natural resource consumption (Ichimura, 2003).

To address these challenges, cities worldwide are adopting the Smart City concept, which aims to leverage information and communication technologies to improve urban living conditions and create more efficient and sustainable cities (Syalianda & Kusumastuti, 2021; Zubizarreta et al., 2016). In Indonesia, the government promotes Smart City adoption in various cities and districts through the "Towards 100 Smart Cities" initiative as a solution to increasingly complex urban issues (Rizkinaswara, 2022). Smart City not only focuses on utilizing technology to optimize public services but also emphasizes more integrated urban planning, enabling a more structured and responsive city management system that meets the needs of its residents.

One of the key technologies driving and supporting Smart City implementation, particularly in infrastructure planning and management, is Building Information Modeling (BIM). BIM is a digital modeling system that enables detailed information management regarding physical data and functional aspects of infrastructure. Examining how BIM operates, several aspects can be connected to the Smart City context. BIM provides a strong foundation for enhancing efficiency in urban infrastructure planning and management, including transportation, utility systems, and

energy usage. It also facilitates interdisciplinary collaboration through data integration, supporting responsive data-driven decision-making in urban management (Al-Ashmori *et al.*, 2020).

Furthermore, the adoption of BIM in Smart City development aligns with the Sustainable Development Goals (SDGs), particularly SDG 11, which focuses on creating inclusive, safe, and sustainable cities. BIM serves as a platform for in-depth data analysis on real-time infrastructure conditions, enabling more responsive planning and decision-making to address the complexities of urbanization (Idrissi Gartoumi & Koumetio Tékouabou, 2023). For instance, BIM can support drainage infrastructure planning and monitoring in flood-prone areas by modeling and simulating water flow throughout the city's drainage network. This capability allows city governments to identify high-risk areas and respond quickly and effectively during floods. This is in line with SDG 11, which aims to create inclusive, safe, and sustainable cities by mitigating risks in urban infrastructure planning and design.

However, BIM implementation in Smart City development in Indonesia remains limited and underexplored. This largely due to several issues, such as a shortage of skilled professionals, high initial implementation costs, and the absence of clear regulatory framework to support its widespread adoption (Heryanto *et al.*, 2021a; Telaga, 2018). Despite these obstacles, BIM offers numerous benefits, such as improved efficiency, better data management, and enhanced collaboration in infrastructure planning and management. Technology holds significant potential to accelerate and optimize Smart City development in a more effective and integrated manner.

Therefore, it is essential to examine the key challenges and opportunities associated with BIM implementation within the Smart City context in Indonesia. This analysis can serve as a valuable contribution to policy development and strategic decision making by the government and other stakeholders. Accordingly, this paper critically investigates the current state of BIM adoption in Indonesia and offers insights to support more sustainable and efficient urban environments. Although the primary focus is on Indonesia, the findings are relevant to other developing countries undergoing similar transitions in urban governance. Lessons drawn from the Indonesian experience can provide transferable knowledge to enhance Smart City strategies in comparable regional contexts.

METHODOLOGY

This paper employs a narrative literature review method to explore the challenges and opportunities of Building Information Modeling (BIM) implementation in Smart City development in Indonesia. The review is based on collecting and analyzing various academic literature, research articles, and government publications related to BIM and Smart City implementation. The research framework and flow are depicted in Figure 2. The literature review process begins with defining the objectives and scope of the discussion, specifically focusing on the challenges and opportunities of BIM implementation in supporting Smart City development in Indonesia. Literature searches were conducted through platforms such as Google Scholar, ScienceDirect, ResearchGate, and other academic journals using the following keywords: (a) Smart City, (b) BIM Implementation, (c) Opportunities and Challenges of BIM Use, (d) BIM Impact on Smart Cities, (e) BIM Use in Indonesia, (f) BIM Use in Singapore, and (g) BIM Integration with Other Technologies. The keyword selection was based on their relevance to the objectives and scope of the study.

Singapore was selected as the primary comparator due to its geographic proximity and its leading role in Smart City and BIM implementation within the Southeast Asian region. As a highly urbanized and technologically advanced city-state, Singapore provides a useful benchmark for evaluating the potential trajectory of BIM integration in Indonesia. The comparison offers valuable insights into how digital innovation, regulatory frameworks, and cross-sector collaboration can support Smart City development in contexts that, while distinct in scale and governance, share regional characteristics and urbanization challenges.

The selection process involved choosing literature that met the following criteria: (a) BIM's impact on Smart Cities, (b) Challenges and opportunities in BIM implementation, (c) BIM in supporting urban infrastructure planning and development, and (d) BIM applications in solving urban and construction industry issues. During the literature search, studies that were not relevant were eliminated, including topics such as (a) BIM implementation in countries other than Indonesia and Singapore, (b) BIM and Blockchain integration, (c) AI applications in Smart Cities, and (d) BIM use in construction waste management and demolition. Based on the literature review and analysis, the discussion is categorized into the following sections: Understanding BIM and Smart City, The Role of BIM in Smart City Development, BIM Implementation and Its Impact on Smart Cities in Singapore, BIM Implementation in Indonesia, Case Studies on BIM Use in Urban Infrastructure Development in Indonesia, Challenges of BIM Implementation in Smart Cities in Indonesia, and Opportunities for BIM Implementation in Smart Cities in Indonesia.

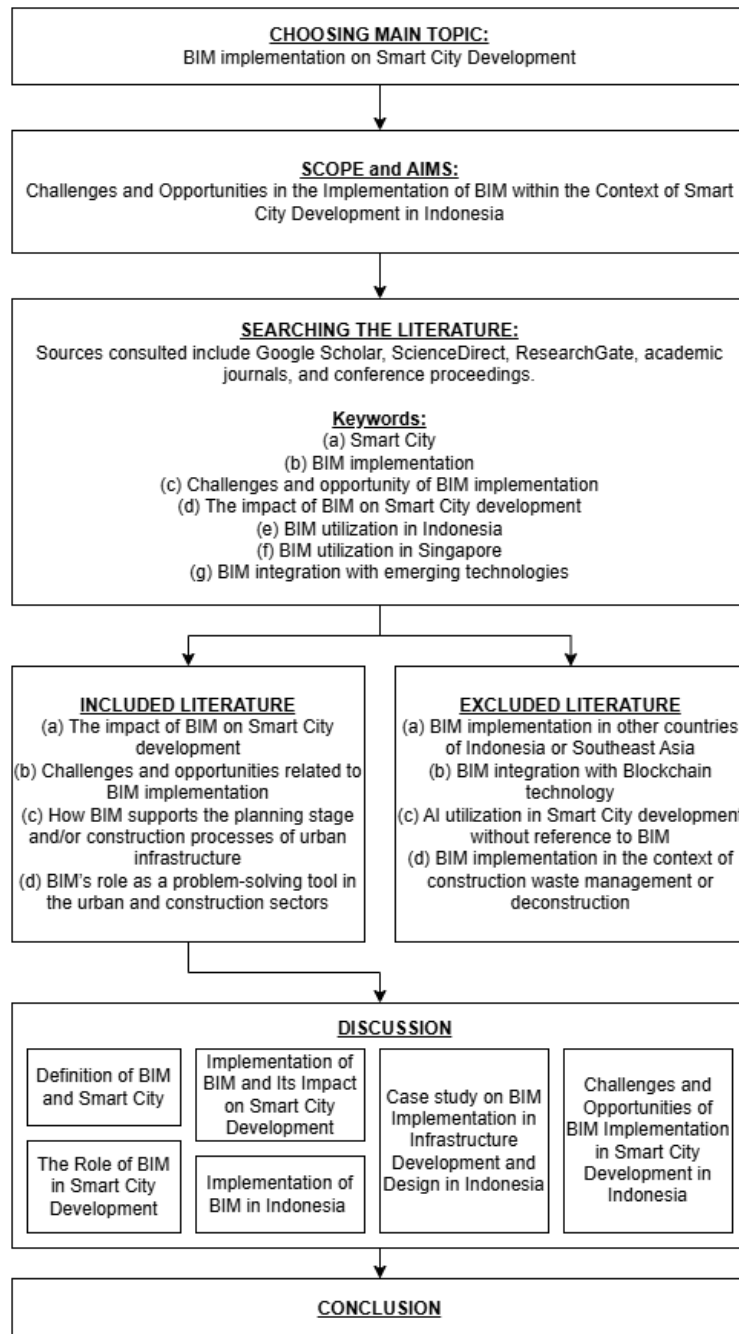


Figure 1. Research Framework

DEFINITION OF BIM AND SMART CITY

A Smart City is a city concept designed to address issues arising from urban development and urbanization by leveraging technology to enhance operational efficiency, environmental sustainability, and the quality of life for citizens (Syalianda & Kusumastuti, 2021). A Smart City utilizes and integrates various technologies such as the Internet of Things (IoT), Geographic Information Systems (GIS), and data analytics to optimize the management of various urban life aspects more effectively, including transportation, energy, and public governance (Safari Bazargani et al., 2021). This concept originates from the idea that cities can utilize information and communication technologies to address urban challenges such as pollution, congestion, management, planning, and communication (Goyal et al., 2020). The Smart City framework is based on six key dimensions classified by Europe: Smart Economy, Smart People, Smart Living, Smart Governance, Smart Mobility, and Smart Environment, as illustrated in Figure 2. Each dimension plays a crucial role in ensuring the successful implementation of a Smart City (Zubizarreta et al., 2016).

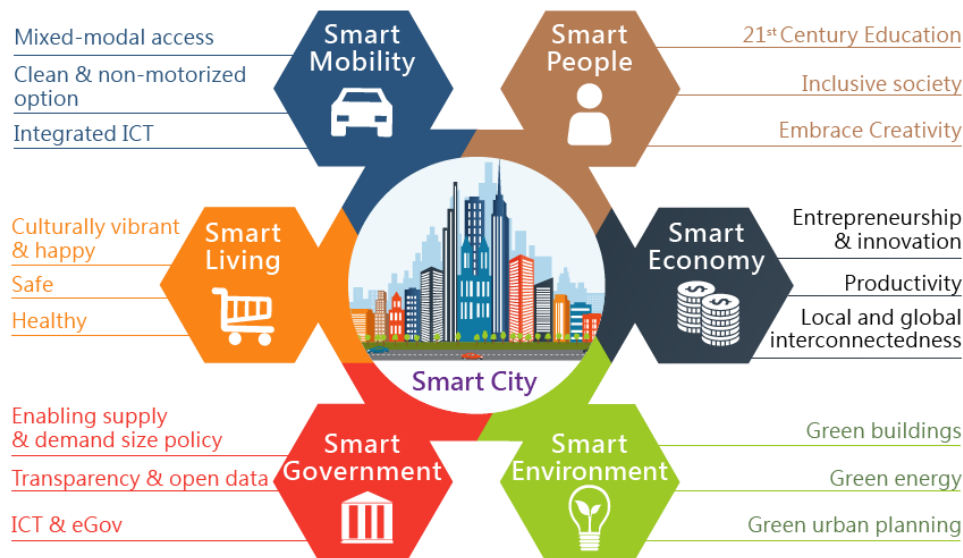


Figure 2. The Six Pillars of Smart City: Mobility, Living, Government, Environment, Economy, and People
(Source: *InsightsonIndia.com*, 2024)

Meanwhile, Building Information Modeling (BIM) is a technology that digitally represents data and information on the physical and functional characteristics of infrastructure. BIM enables various stakeholders, including architects, engineers, contractors, and owners, to collaborate using a single integrated digital model (Heryanto et al., 2021). BIM also supports the entire project lifecycle, from planning, design, and construction to operations, maintenance, and demolition stages (Telaga, 2018). It allows for the simulation of real-world project conditions, enabling the detection of potential issues and more responsive data-driven decision-making. Additionally, BIM enhances coordination and interdisciplinary collaboration to minimize errors during project planning and construction phases (Goyal et al., 2020; Latupeirissa & Arrang, 2024).

The implementation of BIM in Smart Cities can take various forms, including infrastructure modeling and simulation, transportation route management, public utility management, and energy and environmental monitoring. Through collaboration with other technologies such as Geographic Information Systems (GIS) and the Internet of Things (IoT), BIM can support real-time infrastructure monitoring, such as road conditions or drainage systems. This enables city governments to conduct predictive monitoring and maintenance, reducing the risk of unexpected damages and accidents (Goyal et al., 2020). Therefore, BIM implementation should be optimally utilized in Smart City management and development, integrating directly with technology to create a more effective, responsive, and sustainable urban environment. BIM technology has the capability to facilitate and accelerate Smart City development by enhancing the implementation of its six key dimensions, which are explained in detail as follows:

Smart Economy

This dimension emphasizes enhancing a city's competitiveness through innovation, entrepreneurship, and productivity (Zubizarreta et al., 2016). The integration of BIM with Smart City initiatives enables the provision of a comprehensive and integrated database for economic development analysis aligned with urban planning. This enhances economic planning efficiency and supports Gross Domestic Product (GDP) growth (Ismail et al., 2017). Using BIM, economic data related to the city can be collected and integrated into a single platform, facilitating targeted business and investment growth planning. Additionally, BIM supports optimized urban infrastructure planning by identifying specific building needs. Through BIM-based simulation and data visualization, cities can allocate budgets more efficiently and strategically to support economic sectors requiring development (Goyal et al., 2020).

Smart People

This aspect focuses on improving the quality of an educated, inclusive, and creative society with high public participation (Zubizarreta et al., 2016). BIM supports education and citizen engagement in urban planning through infrastructure project visualization and city modeling. With access to detailed infrastructure data, the public can better understand urban development and the impact of projects on the environment (Goyal et al., 2020). This technology also promotes technological literacy and community involvement in urban planning, fostering a more inclusive and collaborative urban environment (Wu et al., 2021).

Smart Living

This dimension encompasses quality of life through efficient public services, including healthcare, education, and security (Zubizarreta et al., 2016). BIM supports Smart Living by providing real-time data monitoring and information on infrastructure and public facilities. Through BIM integration with other technologies such as IoT, BIM can offer insights into public facility conditions, enabling faster and more effective responses to community needs (Scianna et al., 2022). For example, BIM can monitor building and infrastructure conditions, ensuring their safety and usability. Integration between BIM and IoT facilitates sensory monitoring of infrastructure systems such as electricity, water, energy, security, and comfort, allowing for proactive decision-making and timely actions before critical issues arise (Kim et al., 2018).

Smart Governance

This dimension focuses on transparency and public participation in government decision making (Zubizarreta et al., 2016). BIM plays a role in Smart Governance by providing integrated data and platforms that facilitate coordination among institutions and stakeholders while ensuring transparency in urban project implementation. The available data can be accessed by various stakeholders, allowing citizens to monitor urban project developments and participate in decision-making processes (Idrissi Gartoumi & Koumetio Tékouabou, 2023). This technology also enables governments to conduct more integrated planning using real-time data and relevant analyses. As a result, it reduces the risk of project execution errors and enhances responsive planning and management based on community needs (Goyal et al., 2020).

Smart Mobility

This aspect aims to achieve more efficient and integrated urban mobility (Zubizarreta et al., 2016). BIM can be used for urban transportation system planning and simulation, including transportation route analysis, traffic management, and integration with other technologies such as GIS and IoT. Cities can design efficient transportation infrastructure, reduce congestion, and improve accessibility for all residents (Tripathi et al., 2023). The role of BIM in this aspect can be utilized to assist in the planning and development of transportation infrastructure, as well as daily monitoring with the support of other technologies. BIM aids in analyzing and mapping transportation routes, planning road networks, and assessing the impact of infrastructure development on transportation, thereby creating a more structured and well-planned urban transportation system (Goyal et al., 2020).

Smart Environment

Smart Environment emphasizes sustainable environmental management and the responsible use of resources in urban planning, development, and infrastructure management (Zubizarreta et al., 2016). BIM supports Smart Environment through its Building Energy Modeling (BEM) feature, which enables simulations of energy consumption and emissions in buildings. Additionally, integrating BIM with GIS and IoT allows cities to efficiently monitor and manage resources, supporting long-term environmental sustainability and contributing to climate change mitigation efforts (Idrissi Gartoumi & Koumetio Tékouabou, 2023). BIM can also be used to analyze building energy performance, identify areas requiring improvement to reduce energy consumption, and integrate with other technologies for real-time environmental data collection. This includes air quality monitoring, waste management, urban drainage, and disaster risk assessment (Goyal et al., 2020).

THE ROLE OF BIM IN SMART CITY DEVELOPMENT

Information and data are essential elements in Smart City development, as integrated technology allows complex urban issues to be addressed more easily and efficiently (Lai et al., 2020). Building Information Modeling (BIM) plays a crucial role in supporting Smart City development by providing data that can be integrated with urban infrastructure, including information on building conditions, transportation systems, utility networks, and other public facilities. According to (Goyal et al., 2020), this data enables real-time infrastructure condition monitoring and supports data-driven decision-making to enhance the operational efficiency of cities. Additionally, BIM facilitates the provision of detailed information on aspects such as energy and water management, optimizing resource efficiency. With these capabilities, BIM not only aids urban infrastructure management but also enhances urban planning by providing comprehensive data and information. This enables more effective collaboration among stakeholders and supports the implementation of Smart City initiatives in a more efficient and responsive manner.

BIM plays a crucial role in supporting the development and implementation of Smart Cities, particularly through its ability to integrate with other technologies that aid in the design and management of urban infrastructure. One of BIM's key advantages in the Smart City context is its capability to integrate with Geographic Information Systems

(GIS) and the Internet of Things (IoT) (Tripathi et al., 2023). Through this integration, BIM can consolidate data from various urban systems, enabling real-time infrastructure monitoring and providing more comprehensive data analysis. For instance, in traffic management, data collected from IoT sensors and GIS can be combined with BIM to monitor traffic congestion and identify patterns that support improvements in urban transportation systems. Additionally, BIM facilitates efficient energy consumption monitoring and water management, with continuously updated data ensuring optimal resource usage (Ma & Ren, 2017). The integration of BIM with IoT also allows cities to obtain real-time information on the physical condition of buildings and other infrastructure, which is highly beneficial for predictive maintenance, as illustrated in Figure 3. As a result, cities can undertake maintenance actions more accurately and effectively before damage occurs (Dave et al., 2018).

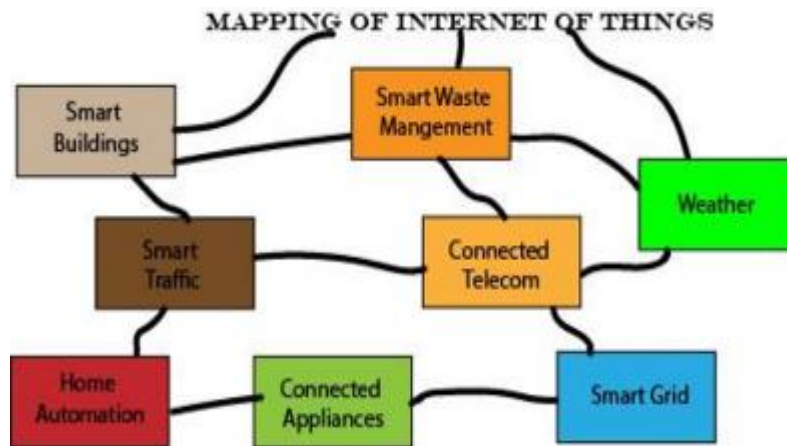


Figure 3. Internet of Things Mapping for Smart City
Source: (Goyal et al., 2020)

Similarly, BIM's modeling capabilities across various dimensions can enhance infrastructure management, improve efficiency, and promote sustainability in Smart City development. Below are some key BIM dimensions that can be applied in Smart City development, according to (Bouhmoud, 2021), which also depicted in Figure 4:

1. **3D (Spatial Dimension):** This dimension represents the physical elements of buildings in volumetric form. The 3D model provides a detailed visualization of urban infrastructure, helping stakeholders better understand designs.
2. **4D (Time Dimension):** BIM 4D integrates time elements into the 3D model, allowing for the scheduling of construction and maintenance activities. With 4D, users can plan construction and maintenance phases more efficiently, ensuring all processes align with predetermined schedules.
3. **5D (Costs Dimension):** This dimension adds cost estimation information to each infrastructure element, from planning to installation and maintenance. BIM 5D aids in calculating total costs or detailed budgets for various components, which is crucial for Smart City project financial management.
4. **6D (Sustainability Dimension):** BIM 6D considers sustainability aspects such as energy performance and the environmental impact of a project. Through this dimension, users can ensure that construction projects meet sustainability standards, including energy efficiency and material recycling.
5. **7D (Maintenance Dimension):** This dimension focuses on facility management, supporting the operation and maintenance of infrastructure throughout the building's lifecycle. With BIM 7D, facility managers can access maintenance schedules, operation manuals, and other relevant information, facilitating more efficient and timely urban infrastructure management.
6. **8D (Safety Dimension):** This BIM dimension emphasizes safety aspects during both the construction and maintenance phases. BIM 8D includes elements related to worker safety, risk management, and data protection, ensuring secure and compliant project execution.

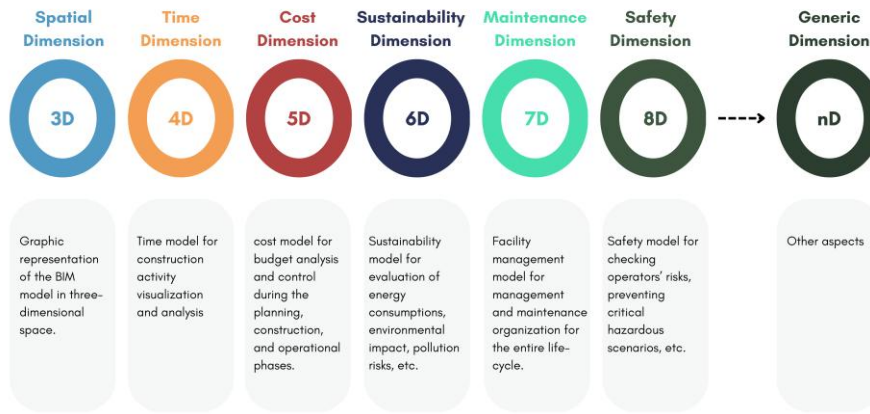


Figure 4. BIM Dimension
Source: (Raza et al., 2023)

The integration between Building Information Modeling (BIM) and Smart City establishes a strong foundation for managing complex urban environments. BIM is not merely a tool for facilitating a single stakeholder but a technology that can be combined with various other technologies to provide better monitoring and more comprehensive analysis, benefiting all parties involved in urban management. This integration strongly supports the Smart City approach, which prioritizes the use and integration of technology to address and overcome urban challenges. BIM’s influence on Smart City development plays a crucial role in enhancing operational efficiency and urban resilience while ensuring sustainability and the city's ability to adapt to increasingly complex urbanization challenges.

IMPLEMENTATION OF BIM AND ITS IMPACT ON SMART CITY DEVELOPMENT

The use of BIM in developed countries began in the early 2000s and has been continuously developed to enhance infrastructure projects more effectively (Pantiga et al., 2021). Singapore implemented Building Information Modeling (BIM) with the launch of its first BIM Roadmap by the Building and Construction Authority (BCA) in 2010. This roadmap aimed to have 80% of the construction industry using BIM by 2015 and was expected to improve construction industry productivity by 25% within a decade (Takashi Kaneta et al., 2016). The Singaporean government structured the roadmap by focusing on regulatory development that emphasized the involvement of all stakeholders, standardizing industry guidelines, and providing technical guidance to ensure smooth implementation across construction projects. This initiative included the launch of the "Singapore BIM Guide" and "BIM Particular Conditions" to serve as industry references in overcoming technical challenges (Teo et al., 2015). The roadmap also identified challenges in BIM adoption and developed five key strategies: leading the public sector, communicating success stories, removing obstacles and barriers, building BIM capability and capacity, and providing incentives for BIM adoption (Jiang et al., 2022), as shown in Figure 5.

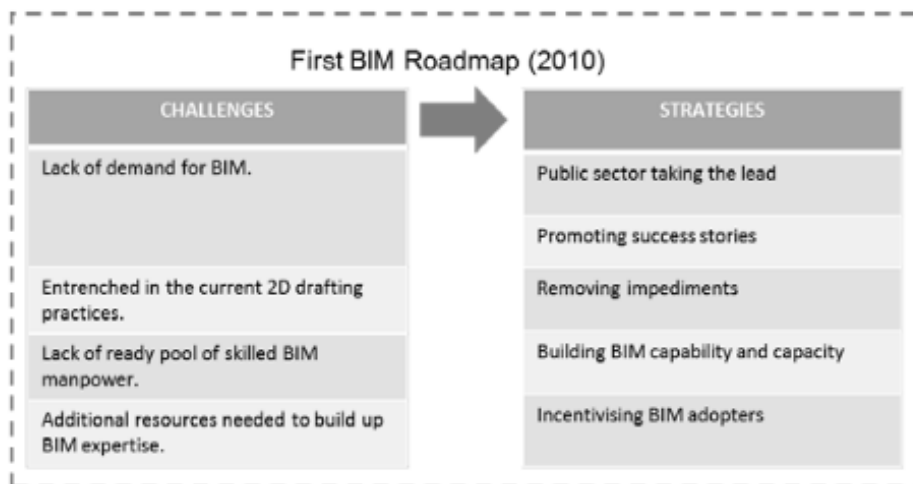


Figure 5. BIM Roadmap of Singapore
Source: (Teo, 2016)

To implement the public sector-led strategy, BCA collaborated with government procurement entities (GPE) to adopt BIM usage in public projects. In 2013, the use of BIM was required for all new building projects with a floor area exceeding 20,000 m², and by 2015, this requirement was expanded to all projects with a floor area greater than 5,000 m² (Teo, 2016). BCA also provided funding to support practitioners in adopting BIM by covering 50% of eligible costs, with a cap of SGD 20,000 per application and SGD 35,000 per discipline. As key drivers and financial facilitators, their role was essential in encouraging broader adoption and participation in BIM implementation (Jiang *et al.*, 2022).

In 2016, Singapore launched its second BIM Roadmap (2016-2020), shifting focus to BIM for infrastructure and asset management, process transformation, as well as research and development of BIM innovations (Hadzaman *et al.*, 2015). This new strategy included the use of BIM for Smart City development, facility management, BIM collaboration through virtual design and construction, and the application of BIM for design manufacturing and assembly (Shen, 2016). Additionally, the Singaporean government initiated the Construction Productivity and Capability Fund (CPCF) with an allocation of SGD 250 million to advance BIM technology in construction. In 2000, the Real Estate Network (CORENET) program was launched as a strategy to transform and support the construction industry through the use of information technology. CORENET serves as a platform for information exchange among all project stakeholders, supporting BIM implementation by allowing involved parties to verify regulatory compliance online (Smith, 2014).

BIM has become a fundamental technology supporting the development of Smart Cities in Singapore, enabling integration with other technologies such as GIS and IoT to facilitate real-time data exchange for urban infrastructure management. This integration provides access to more accurate data, helping cities conduct more effective monitoring and management (Goyal *et al.*, 2020). For instance, data generated by IoT sensors can be used to monitor traffic congestion, which is then analyzed through BIM and GIS to improve transportation systems and enhance urban mobility (Safari Bazargani *et al.*, 2021). Through this approach, Singapore has successfully created a more responsive and efficient city that effectively meets and addresses the needs of its citizens.

IMPLEMENTATION OF BIM IN INDONESIA

The implementation of BIM in Indonesia falls behind the progress seen in developed countries. The first documented use of BIM in Indonesia for construction purposes was in 2012, highlighting a delay compared to developed nations that had already adopted BIM as early as 2000 (Pantiga *et al.*, 2021). In the process of BIM adoption in Indonesia, several significant challenges remain; however, this also presents significant opportunities for the development of the country's construction industry (Ary, 2021). Starting in 2017, the Indonesian government actively promoted BIM adoption among state-owned enterprises to enhance productivity and efficiency in infrastructure development (Heryanto *et al.*, 2021).

To support BIM adoption, the Indonesian government, particularly through the Ministry of Public Works and Housing (PUPR), has issued policies such as Ministerial Regulation PUPR No. 22 of 2018, which requires the use of BIM in state building projects with specific budget thresholds (Wibowo, 2023). PUPR has also established a dedicated team, BIM PUPR, responsible for promoting BIM implementation across government projects. This team actively conducts training, outreach programs, and develops technical standards and a BIM implementation roadmap, as illustrated in Figure 6. The roadmap for BIM adoption in Indonesia consists of several stages, beginning with adoption, digitalization, collaboration, and integration, which are applied from planning to infrastructure maintenance. This initiative aims to enhance digital competency within Indonesia's construction industry, enabling the country to achieve Smart City implementation and compete in regional and global markets (Heryanto *et al.*, 2021).



Figure 6. BIM Roadmap by BIM PUPR
Source: (Heryanto et al., 2021)

There are many challenges in the implementation process in Indonesia, such as a lack of skilled professionals, high costs of hardware and software, low demand, and resistance to change within the construction industry (Puspita & Patriotika, 2020), which can be seen in Figure 7. Although BIM awareness in Indonesia's construction industry is relatively high at 72%, its actual implementation remains low at only 38%. Moreover, BIM usage is mostly limited to conceptual work with 3D modeling, where project data and information are digitized; however, data exchange and collaboration have not yet been widely utilized (Pantiga et al., 2021; Telaga, 2018). Additionally, the government's regulatory framework has not been fully optimized to support widespread BIM adoption. The lack of incentives and clear standards for BIM implementation, particularly for small and medium-sized enterprises, further slows down its development (Puspita & Patriotika, 2020).

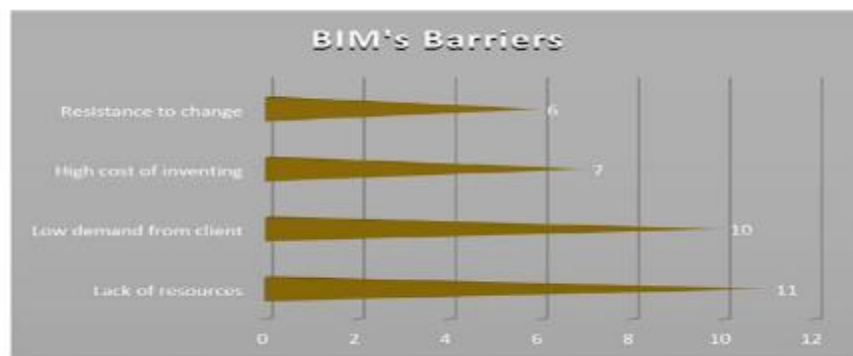


Figure 7. The BIM's Barriers
Source: (Puspita & Patriotika, 2020)

However, the influence of BIM adoption has become evident in several private companies, such as PT Total Bangun Persada and PT Intiland Development, which have utilized BIM for infrastructure projects. BIM has proven to enhance project efficiency and reduce issues among involved stakeholders (Chandra et al., 2017). This demonstrates how BIM significantly impacts the effectiveness of infrastructure project execution, highlighting how technology can contribute to the development of a more efficient and responsive city.

To accelerate BIM adoption, the government is also collaborating with higher education institutions and industry associations to provide training and certification programs for the workforce in BIM. Several universities have incorporated the BIM curriculum into engineering and architecture programs, preparing graduates to meet the demands of digitalization in the construction industry (Wibowo, 2023). This initiative is expected to facilitate the acceleration of BIM adoption in Indonesia and enhance the quality of human resources in the construction sector (Telaga, 2018). However, greater government support is still needed in terms of regulations, incentives, standards, education, investment, and collaboration between the government, private sector, and educational institutions to drive and optimize the broader implementation of BIM in Indonesia.

CASE STUDY ON BIM IMPLEMENTATION IN INFRASTRUCTURE DEVELOPMENT AND DESIGN IN INDONESIA

The implementation of Building Information Modeling (BIM) in Indonesia's construction industry has had a significant impact, presenting both benefits and challenges in infrastructure development and design. Various case studies have demonstrated BIM's great potential in enhancing efficiency and effectiveness throughout construction phases, proving that its adoption can accelerate project timelines and minimize errors in project execution. However, alongside the benefits that BIM offers, challenges remain that need to be addressed for wider adoption in Indonesia's infrastructure development and design.

A case study on the construction of the Islamic University of Malang Hospital building, conducted by (Utari & Pradana, 2023), utilized BIM to analyze work volume by simulating time (4D) and estimating project costs (5D). The study results indicated that the use of BIM significantly improved efficiency in calculating work volume and cost estimation, while also providing 3D model visualization and simulations that helped detect potential errors during the planning stage. This approach has been proven to accelerate the planning and execution process compared to conventional methods, as BIM technology enables accurate cost estimation and precise time projections for project completion.

Similarly, a study by (Berlian *et al.*, 2016), comparing the efficiency of BIM usage with conventional methods in a 20-story building project. The study concluded that BIM could reduce the need for human resources by up to 27% and cut personnel costs by 52%. Additionally, BIM implementation was found to accelerate the planning phase by up to 50% compared to conventional methods. This efficiency is achieved because BIM enhances interdisciplinary collaboration by utilizing 3D models integrated with data and information, enabling faster information exchange and improving coordination among all parties involved in the project.

Another case study was conducted by (Riyadi *et al.*, 2024), on the application of BIM in the planning of the Presidential Palace building in the Nusantara Capital City (IKN) by PT Yodya Karya. The study found that the use of BIM in the planning phase significantly improved efficiency and productivity by transforming work processes into a digital and coordinated system. BIM facilitated data management and integration while providing better design visibility, which helped reduce the risk of errors and enhanced clarity in communication, a crucial factor in large-scale projects. This study highlights the critical role of BIM in optimizing project management, minimizing construction errors, and improving the accuracy and quality of infrastructure project outcomes.

However, despite the significant benefits BIM can offer, its implementation in Indonesia still faces various challenges. For instance, in the expansion project of Terminal 1 (T1) at Juanda International Airport in Surabaya, BIM was utilized to integrate the design and construction processes more collaboratively. (Nugrahini & Permana, 2020) reported that the use of BIM in this project greatly helped reduce design errors and improved clarity and efficiency in coordination among stakeholders. Nevertheless, although BIM has proven to be highly beneficial in organizing, managing, calculating, and supervising construction processes, challenges remain in its implementation. These include the high hardware requirements, substantial investment costs, and regulatory limitations, which often become obstacles for companies in fully adopting BIM technology.

Overall, case studies on the use and implementation of BIM in infrastructure development and design in Indonesia demonstrate that BIM offers significant benefits. These advantages have been proven to enhance project phases by improving time efficiency, reducing costs, and increasing project quality. Although challenges and obstacles remain in implementing BIM technology, these obstacles serve as motivation to continuously improve and accelerate its adoption in infrastructure projects. Given the considerable benefits of BIM, it is crucial for stakeholders to further enhance its comprehensive implementation. While case studies indicate that BIM usage in Indonesia has yet to reach its full potential, its positive impact on the construction industry is already evident. This highlights the need for a strong commitment to expanding BIM implementation in the future.

CHALLENGES OF BIM IMPLEMENTATION IN SMART CITY DEVELOPMENT IN INDONESIA

The implementation of Building Information Modeling (BIM) in Indonesia still faces various challenges and issues in supporting Smart City development. There are three key aspects that pose challenges in BIM implementation in Indonesia: technology, process, and protocol (Pantiga *et al.*, 2021). Within these aspects, several significant challenges hinder the adoption of this technology in Indonesia, including a lack of skilled professionals, limited technological infrastructure, high implementation costs, resistance to change, and inadequate regulatory support (Utomo & Rohman, 2019).

1. Limited Skilled Human Resources

The lack of professionals with expertise in BIM presents a significant challenge in implementing BIM technology in Indonesia. This issue arises due to the limited availability of training and skill development programs related to BIM, resulting in restricted practical knowledge among professionals (Utomo & Rohman, 2019). This problem is further exacerbated by the lack of participation from the government and educational institutions in Indonesia, which have yet to offer comprehensive training programs or curricula on BIM. As a result, many workers are unable to adopt and adapt to the digital transformation required for BIM implementation in the construction industry (Pantiga et al., 2021).

2. Limited Technological Infrastructure

Adequate technological infrastructure is essential for BIM implementation in Indonesia, including fast and stable internet networks, as well as sufficient hardware and software (Criminale & Langar, 2017). However, Indonesia's information technology infrastructure remains insufficient due to a lack of government investment in promoting BIM adoption. This digital infrastructure deficiency becomes a major obstacle to the optimal application of BIM and hinders the full digitalization of the construction sector (Pantiga et al., 2021). Without adequate technological infrastructure, industry players will struggle to fully utilize BIM's potential to enhance efficiency and collaboration in projects.

3. High Implementation Costs

The high investment required for BIM implementation is another significant challenge in its adoption process in Indonesia. Implementing BIM involves substantial costs, including purchasing technological infrastructure such as software and hardware, as well as training programs to enhance workforce skills (Pantiga et al., 2021). Many small to medium-sized construction companies are unable to adopt BIM due to its unaffordable investment costs, leading them to continue using traditional methods that are perceived as more economical (Utomo & Rohman, 2019).

4. Resistance to Change

The tendency to rely on previous technologies is a key factor that arises due to fears of workflow disruption. Many construction companies in Indonesia still prefer traditional methods because of the high costs, as well as the time and effort required to learn and implement BIM into project workflows (Utomo & Rohman, 2019). This resistance is particularly evident among small to medium-sized companies that lack the resources to invest in technological changes. As a result, BIM implementation is mainly driven by the government, leading to minimal adoption in the private sector due to the lack of strong incentives (Pantiga et al., 2021; Pratama, 2022).

5. Lack of Supporting Regulations

The lack of strong regulatory support from the government significantly impacts BIM implementation efforts in Indonesia. Although some initiatives have been undertaken, such as the Ministry of Public Works and Housing (PUPR) issuing regulations related to BIM adoption, their implementation in practice remains limited and inconsistent (Pantiga et al., 2021). Additionally, existing regulations do not mandate the use of BIM in all infrastructure projects, particularly in the private sector. As a result, there is no strong incentive for construction companies to adopt this technology on a wider scale (Pratama, 2022).

These challenges show that while many developing countries encounter similar challenges in BIM adoption, the situation in Indonesia is further complicated by its decentralized governance system and vast regional disparities in digital readiness. The autonomy of local governments leads to inconsistent policy enforcement, uneven infrastructure investment, and fragmented capacity-building efforts across regions. This unique administrative context in Indonesia requires more localized strategies and stronger coordination mechanisms between central and regional authorities to ensure equitable and effective BIM integration across the country.

OPPORTUNITIES FOR BIM IMPLEMENTATION IN SMART CITY DEVELOPMENT IN INDONESIA

The implementation of Building Information Modeling (BIM) presents vast opportunities to support and enhance Smart City development in Indonesia. One of the key opportunities provided by BIM is its ability to improve efficiency in urban infrastructure planning, construction, and operations through its integration with information technology. BIM enables the creation of digital infrastructure models containing data and information, facilitating seamless data exchange and better collaboration among stakeholders (Aziz et al., 2016). Consequently, this integration accelerates decision-making processes and enhances the accuracy of planning at every stage of Smart City development (Goyal et al., 2020).

The ability of BIM to integrate with other technologies also presents opportunities for urban development in Indonesia. The integration of technologies such as Geographic Information Systems (GIS) and the Internet of Things (IoT) plays a crucial role in Smart City development, as it enables real-time monitoring and data analysis of urban infrastructure, thereby enhancing city services such as transportation and energy management (Tripathi et al., 2023). For instance, data generated by IoT sensors can be incorporated into BIM models to monitor traffic congestion and optimize transportation routes, reducing urban gridlock. This capability contributes to the creation of more responsive and efficient cities that effectively meet the needs of their residents (Idrissi Gartoumi & Koumetio Tékouabou, 2023).

BIM also plays a crucial role in environmental sustainability by utilizing technology to enhance energy efficiency. Through digital modeling, BIM enables monitoring and designing energy-efficient buildings, thereby reducing carbon emissions and promoting more effective resource utilization (Asmar, 2013). Additionally, BIM can support sustainable infrastructure planning, such as the design and monitoring of drainage systems and improved water management. This capability contributes to the development of well-maintained and sustainable urban environments (Goyal et al., 2020).

From an economic perspective, although the investment costs for BIM implementation are substantial, its adoption in Indonesia presents an opportunity to enhance the competitiveness of the country's construction sector in the global market. BIM enables construction companies to improve quality, productivity, efficiency, and project speed by minimizing potential errors and modifications during the construction process (Heryanto et al., 2021). It also helps identify and analyze risks at every stage of development, thereby reducing and mitigating costs associated with potential errors (Puspita & Patriotika, 2020). Furthermore, BIM implementation creates an opportunity to develop the skills of Indonesia's workforce, equipping them with technological expertise for future industry demands (Wibowo, 2023).

The opportunities for BIM implementation in Indonesia are vast, offering a more effective and responsive approach to urban management. If these opportunities are fully utilized, BIM can play a crucial role in improving the quality of urban life and creating safer and more comfortable urban environments. Therefore, the involvement of various stakeholders, including the government, educational institutions, and both private and public sectors, is essential in maximizing the potential of BIM for Smart City management and development in Indonesia.

The challenges discussed in this paper point to a range of technological, financial, regulatory, and institutional barriers that shape BIM implementation in Indonesia. However, these are accompanied by emerging opportunities, particularly in the form of ongoing public-sector initiatives, policy efforts, and infrastructure programs. Table 1 summarizes the main challenges and corresponding opportunities derived from the findings, serving as a practical reference for future implementation strategies.

Table 1. Summary of Key Challenges and Opportunities

Category	Challenges	Opportunities
Human Resources	Limited skilled professionals; lack of training programs	Government and institutional support to increase BIM training availability
Technological Infrastructure	Inadequate IT infrastructure; limited digital access across regions	Strengthen national digital infrastructure to support BIM platforms
Financial/Cost	High costs of software, hardware, and training	Promote cost-sharing models or phased implementation to reduce initial barriers
Regulatory & Policy	Lack of clear mandates; weak policy enforcement	Expand BIM-related regulations; apply policies more consistently across sectors
Governance Context	Decentralized government structure; regional disparities	Encourage stronger coordination between central and regional governments

CONCLUSION

Building Information Modeling (BIM) and the Smart City concept play complementary roles in managing urban areas more efficiently, responsively, and sustainably. BIM supports urban planning, construction, and infrastructure management through its ability to integrate technology digitally. This integration aligns with the Smart City initiative, which aims to comprehensively address urban challenges through technological solutions. However, BIM implementation in Indonesia still faces numerous challenges, including a shortage of skilled professionals, inadequate technological infrastructure, high investment costs, resistance to change, and unclear regulations.

Despite these obstacles, BIM presents significant opportunities, particularly in enhancing efficiency, coordination, environmental sustainability, and competitiveness within the construction sector. BIM adoption in Indonesia remains largely untapped, offering vast potential for expansion. The integration of BIM with GIS and IoT could advance urban infrastructure planning, enabling real-time and responsive city management. BIM holds substantial potential to positively impact Smart City development in Indonesia by improving urban management

efficiency, reducing errors, and facilitating faster and more accurate decision-making, ultimately contributing to a higher quality of urban life.

This paper outlines the key challenges to be addressed and the opportunities to be utilized in implementing BIM for Smart City development in Indonesia. These insights can support the government and stakeholders in evaluating and pursuing the potential adoption of BIM. To build on this research, future studies could investigate the practical outcomes of BIM implementation across different project types and scales, as well as explore its deeper integration with emerging technologies. Expanding this knowledge can contribute to more inclusive, sustainable, and technology-driven urban transformation, not only in Indonesia but also in other developing countries facing similar urbanization challenges.

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