Exploring the Potential of BIM-Based QTO for Hospital Structural Work to Support SDGs through Sustainable Construction

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ABSTRACT

Keywords:
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Quantity Take-Off (QTO) is a critical stage in the planning and execution of construction projects, particularly in ensuring the accurate and efficient calculation of material requirements. QTO methods can be performed using conventional approaches or through Building Information Modeling (BIM)-based systems. The use of BIM in the QTO process has proven to enhance time efficiency, improve the accuracy of material volume calculations, and facilitate data validation and revisions. Case studies on hospital construction projects in Semarang, Samarinda, and Boyolali demonstrate that BIM can reduce calculation errors to as little as 1–2% and decrease structural costs by up to 9.25%. This is particularly crucial for hospital projects that require high precision in structural planning. Moreover, the application of green construction principles and environmental impact assessments using the Life Cycle Assessment (LCA) method represent strategic approaches to support sustainable development. Despite its advantages, BIM implementation still faces significant challenges, including high software licensing costs, a lack of skilled professionals, and limited government support. These barriers are commonly found in regions such as Bali, Jambi, and various areas in Malaysia. Therefore, to maximize the potential of BIM in enhancing efficiency and sustainability in construction projects, a synergy is needed between human resource development, government policy, and the standardization of BIM practices in the field.

INTRODUCTION

The growing global demand for resilient infrastructure has underscored the need to integrate sustainability into construction practices (Zuo & Zhao, 2014). Among various types of infrastructure, healthcare buildings—especially hospitals—hold a vital role in achieving several Sustainable Development Goals (SDGs), including Good Health and Well-being (SDG 3), Industry, Innovation, and Infrastructure (SDG 9), and Sustainable Cities and Communities (SDG 11) (Wang et al., 2021). However, hospital construction projects often present environmental challenges due to their resource-intensive nature and high energy demands, making them critical targets for sustainability interventions (Geng et al., 2015). Traditional construction approaches are frequently criticized for being inefficient, particularly due to excessive material waste and cost overruns (Luangcharoenrat et al., 2019).

One key factor that influences a project's cost, schedule, and performance is the accuracy of early-stage quantity estimation. Quantity Take-Off (QTO) plays a vital role in this phase, yet conventional manual QTO methods are prone to errors and inconsistencies—especially in complex, large-scale projects such as hospitals (Shen et al., 2010; Kim et al., 2016). To address these limitations, Building Information Modeling (BIM) has emerged as a transformative technology in the construction industry. BIM facilitates enhanced collaboration among stakeholders and supports accurate and efficient decision-making

throughout the project lifecycle (Succar, 2009). In the context of QTO, BIM allows for automated quantity extraction, improving precision, minimizing errors, and significantly reducing time spent on manual calculations (Monteiro & Martins, 2013). This study explores the potential of BIM-based QTO in hospital structural works as a means to support sustainable construction and contribute to the realization of the SDGs

RESEARCH METHOD

This study applies the literature review method as a way to deepen conceptual understanding of a particular subject area by drawing insights from existing research (Cooper, 1998). Rather than simply summarizing prior work, this method allows the researcher to engage critically with the literature, surfacing underlying assumptions and exposing areas that have not yet been fully addressed (Snyder, 2019). One of the key strengths of a literature review is its ability to question and critique taken-for-granted assumptions that often go unnoticed in academic discussions (Cooper, 1998). It also proves useful in identifying inconsistencies or contradictions between different studies, which can help sharpen the focus of future research (Snyder, 2019).

In addition to offering critical insight, a literature review contributes to establishing a strong theoretical foundation, connecting current investigations with established frameworks and scholarly traditions (Boote & Beile, 2005). Another important function of the literature review is to locate areas where studies are missing, limited, or underdeveloped, thus, guiding where new contributions can be made (Paré et al., 2015). Finally, literature reviews are valuable for clarifying and standardizing key terms, which is particularly helpful when working across studies that may use similar language differently (Jesson et al., 2011).

RESULTS AND DISCUSSION

A. BIM-Based QTO in Structural Works

The Quantity Take-Off (QTO) method is a vital stage in the planning and execution of construction projects, particularly in ensuring that material requirements can be calculated precisely and efficiently (Mattern et al., 2018). In general, QTO involves calculating the dimensions of building materials, such as volume, length, area, width, and so on. In its application to structural work, QTO can be categorized into two methods: the conventional method and the Building Information Modeling (BIM)-based method (Magfirona et al., 2023).

BIM offers various advantages in the QTO process. Building Information Modeling (BIM) technology enables the simulation of construction projects in three dimensions (3D), providing accurate building visualization and facilitating data validation and revision (Apriansyah, 2021). Moreover, BIM allows for the automation of material volume calculations, which directly saves time and minimizes the potential for calculation errors. As a result, the accuracy of measurements is significantly higher compared to the conventional method (Lestari et al., 2021; Rugas et al., 2024).

Furthermore, QTO is a crucial process in construction project management as it is directly related to estimating material requirements. The results of QTO serve as the foundation for preparing project cost estimates or the Bill of Quantities (BoQ). Therefore, accuracy in

the QTO process greatly determines the effectiveness and efficiency of material usage and plays a key role in controlling the overall construction project costs (Sadad & Noviantoro, 2024).

B. Application of BIM QTO in Hospital Construction

The application of Building Information Modeling (BIM) in the Quantity Take-Off (QTO) process for hospital construction has proven to enhance both efficiency and accuracy in estimating structural work volumes. This is particularly crucial as hospitals are complex and vital public buildings that require precise structural planning and accurate material calculations. Through BIM technology, material quantity calculations can be performed automatically based on integrated 3D models, thereby reducing errors from manual measurements and accelerating the validation and revision process (Kusumaningroem & Gondokusumo, 2023).

The effectiveness of BIM in QTO is also reflected in a case study of a hospital project in Semarang, which showed a significant difference of up to 10% between manual QTO results and those using BIM, with the BIM method demonstrating more consistent and efficient outcomes (Irawan et al., 2023). Similarly, in the case of an eye hospital project in Samarinda, the discrepancy in structural material calculations such as concrete and reinforcement between manual and BIM methods was only around 1–2%, indicating a high level of accuracy in BIM-based QTO (Handayani et al., 2021).

Comparable findings were also observed in a surgical hospital building project, where the use of BIM led to material efficiency of 1.67% for concrete and 3.32% for reinforcement (Retno Asih et al., 2022). In addition to quantitative efficiency, the success of BIM-QTO implementation is also supported by factors such as data interoperability between models and the completeness of the Bill of Quantities (BoQ), which have been shown to improve overall structural cost performance (Meisaroh et al., 2021). Furthermore, in the case study of RSUD Boyolali, the implementation of 5D BIM using Cubicost software resulted in a 9.25% reduction in structural costs, highlighting the tangible potential of BIM technology in supporting budget management for healthcare facility construction (Saputra et al., 2024).
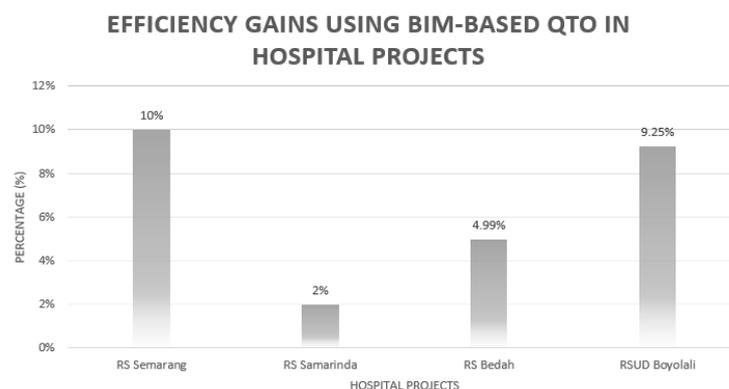
Figure 1. *Efficiency Gains Using BIM-Based QTO in Hospital Project*
Source: Personal Data, 2025

The following chart efficiency gains using BIM-based methods in the Quantity Take-Off (QTO) process across several hospital projects. The graph illustrates that the BIM method offers higher efficiency and accuracy compared to the manual approach, particularly in the RSUD Boyolali project, which recorded cost savings of up to 9.25%.

C. BIM Contribution to Sustainable Construction

With the rapid development of the construction industry in Indonesia, a sustainable development approach is needed to reduce negative impacts on the environment. One strategic solution that can be implemented is the concept of green construction, which emphasizes energy efficiency, the use of environmentally friendly materials, and improved waste management (Majid, 2023; Mahardika et al., 2025). This concept not only focuses on resource efficiency but also incorporates principles of environmental preservation, material regeneration in line with the circular economy concept, energy savings, and the application of eco-friendly technologies.

In line with this, green building has become a crucial approach in supporting low-carbon development. This is pursued through policies and programs that focus on improving the efficiency of energy, water, and eco-friendly material use, while also encouraging the adoption of low-carbon technologies in the construction sector (Adi & Andriyani, 2023). To support such sustainable development efforts, environmental assessments through the Life Cycle Assessment (LCA) method are essential, as they provide a comprehensive evaluation of environmental impacts from the beginning to the end of a building's life cycle.

In addition, social and economic impact analyses must also be considered due to their relevance to holistic sustainability aspects. This process involves identifying key environmental impact indicators such as carbon emissions, natural resource utilization, and construction waste management systems. The analysis is conducted comprehensively across the pre-construction, construction, and operational or post-construction phases (Kimsan, 2023). Furthermore, the application of Green Lean Construction (GLC) principles in construction projects is considered to offer significant benefits, including improved resource efficiency, reduced environmental impact, and enhanced quality and effectiveness of the construction process itself (Irmawaty et al., 2025).

D. Recent Challenges and Future Potentials

Various studies have shown that the implementation of Building Information Modeling (BIM) in the construction sector still faces significant challenges, both at national and regional levels. In Johor, Malaysia, construction stakeholders have identified key barriers such as the high cost of software licenses, limited understanding of BIM's benefits, and a lack of government regulations supporting the adoption of this technology (Roseli et al., 2024). A similar situation is found in Bali, Indonesia, where the adoption rate of BIM remains low. This is mainly due to high costs, particularly related to software licensing, a shortage of skilled professionals, limited government support, resistance to changes in work processes, and the lack of established BIM standards in the field (Megapathi et al., 2021).

Likewise, construction companies in Jambi also encounter comparable obstacles. These include limited understanding of BIM and its long-term benefits, insufficient government support, high hardware requirements, the expensive cost of BIM licenses, and low market or client demand (Azrita et al., 2024). In Malaysia, particularly among small and medium-sized contractors (SMEs), challenges include lack of experience and skilled labor, low user awareness, and fragmentation within the construction industry that slows the adoption of BIM for project risk management (Ismail et al., 2022).

Furthermore, in the context of the quantity surveying profession in Malaysia, although awareness of BIM is relatively high, actual implementation remains low. This is due to a lack of deep understanding of BIM's benefits, unclear business value, and limited structured training and implementation strategies (Mustapa et al., 2022). In addition, a study in Sabah, Malaysia, revealed resistance to shifting from conventional work methods, high software costs, and a shortage of competent personnel to operate BIM tools. Although the government has provided support through standardization efforts and limited financial assistance, these barriers remain major obstacles to the widespread adoption of BIM (Jamaludin et al., 2022).

CONCLUSION

The findings of this study indicate that the implementation of Building Information Modeling (BIM) in Quantity Take-Off (QTO) for structural works—particularly in hospital construction—significantly enhances material calculation accuracy, cost efficiency, and time effectiveness. Case studies demonstrate up to 9.25% savings in structural costs, while also supporting sustainable construction practices through reduced waste and optimized resource use. However, implementation challenges such as high software licensing costs and a shortage of skilled professionals remain major barriers. Future research should focus on strategies to increase BIM adoption, including technical training integration and stronger government policy support. These findings are expected to encourage practitioners, academics, and policymakers to further explore and expand the application of BIM technology in construction projects across Indonesia.

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