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DEFINING GREEN BUILDING CRITERIA FOR BUILDING INFORMATION MODELING-BASED RATING SYSTEMS

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ABSTRACT

As sustainability becomes increasingly central to architectural and construction practices, robust frameworks are needed to evaluate and guide the implementation of green building (GB) standards. Integrating Building Information Modelling (BIM) with GB criteria presents a promising approach to advancing sustainable construction. BIM provides a comprehensive digital representation of a building's physical and functional characteristics and has the potential to streamline sustainability assessments by aligning traditional GB standards with data-driven design and evaluation processes. In Indonesia, the adoption of GB principles remains limited due to the complexity of building design and evaluation. This paper explores GB criteria tailored for BIM-based rating systems based on the Regulation of the Minister of Public Works and Public Housing No. 21 of 2021. Data were collected through a literature study and analyzed using expert judgment. The findings classify the criteria into two categories: (1) those that can be directly integrated with BIM and (2) those that require manual assessment. The study identifies 18 criteria suitable for BIM integration and 11 that depend on manual processes. These results illustrate the opportunities and constraints of using BIM to support GB assessments.

Keywords: *Building Information Modelling; Green Building; Rating System.*

1. INTRODUCTION

The growing urgency of climate change and rapid urbanization has increased the pressure on the building and construction sector to adopt sustainable practices. This sector is

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responsible for nearly 40% of energy-related carbon emissions worldwide. As a response, many governments now promote the use of green building (GB) standards to reduce environmental impacts. In Southeast Asia, GB initiatives have become more prominent part of national strategies for sustainable development. GBs not only provide environmental benefits but also reduce life-cycle costs (Zuo & Zhao, 2014). GBs help conserve natural resources, enhance occupant well-being, and improve building performance (Sari et al., 2022). Various GB technologies have been developed to suit local construction contexts, although most research still focuses on isolated components rather than integrated solutions.

To achieve long-term sustainability in building projects, stakeholders need a comprehensive understanding of how to design, construct, operate, and manage buildings responsibly. As a result, sustainability assessment has become an essential approach in the development process (Reed et al., 2017). Green Building Rating Systems (GBRSs) support this goal by providing structured tools that evaluate building performance against defined sustainability criteria. These systems help ensure that sustainable design requirements are met and that environmental objectives are achieved (Romano & Riediger, 2020). In Indonesia, however, the use of GBRS remains limited by challenges in adapting frameworks to national regulations and local conditions. Addressing these constraints is necessary to accelerate the adoption of sustainable construction practices.

While GBRS provide a strong foundation for sustainability evaluation, their effectiveness can be improved through digital tools such as Building Information Modelling (BIM) (Seghier et al., 2018). BIM provides a centralized platform for visualizing and managing building data. It supports sustainability assessment by enabling automation, improving accuracy, and simplifying the certification process (Doan et al., 2023). BIM is also capable of supporting detailed modelling and simulation at every building's life cycle.

Over the past two decades, BIM has transformed the architecture, engineering, and construction (AEC) industry, and has been widely used for communication and coordination in design, construction, and facility management (Wong & Kuan, 2014). The main benefits of BIM include better decision-making, faster access to information, improved performance analysis, and more efficient GB certification (Ilhan & Yaman, 2016). Studies show that BIM-based GB evaluations can enhance building performance by 31.5%, reduce energy use, and improve indoor comfort (Guo et al., 2021). BIM has already supported green certification frameworks in several countries. In New Zealand, BIM is used for 75% of the Green Star Certification Tool (GhaffarianHoseini et al., 2017). In Australia, it contributes to 66% of credits under the Green Star system (Gandhi & Jupp, 2014). It has also been used in Canada (Jalaei & Jrade, 2014), Portugal (Carvalho et al., 2021), and Malaysia (Solla et al., 2022) to support national GB certifications.

Although these developments show clear progress, most studies still focus on limited aspects of integration between BIM and GBRS. Researchers have primarily explored energy efficiency, material selection, or partial system automation. For example, the BIM-based GBRS developed by Romano and Riediger (2020) emphasizes energy-related features. The framework developed by Rahman et al. (2021) includes only Energy and Atmosphere (EA) and Material Resources (MR) in alignment with LEED. Additional studies have examined the use of BIM for automatic assessments (Motamedi et al., 2017), green certification support (Seyis et al., 2021), and verification of sustainability goals

(Alwan et al., 2015). However, few studies have offered a complete view of how national GB criteria can be fully embedded within BIM-based systems.

This research focuses on Indonesia's Regulation of the Minister of Public Works and Public Housing No. 21 of 2021, which aims to identify which of these criteria are relevant to BIM-based evaluation and to classify them based on their compatibility with BIM tools through expert validation. The goal is to support the development of a more structured and technology-enabled approach to GB evaluation in Indonesia. The findings are expected to provide practical guidance for BIM practitioners, researchers, and policymakers in strengthening GB practices within the Indonesian context.

2. GREEN BUILDING RATING SYSTEM CATEGORIES

GB refers to a structured approach that minimizes the negative environmental impact of construction activities while preserving natural resources across a building's life cycle (Sari et al., 2022). Indonesia is one of the developing countries that attempts to massively adopt GB concept. Indonesia's GB assessment framework, outlined in the Regulation of the Minister of Public Works and Public Housing, organizes criteria into six main categories: Appropriate Site Development (ASD), Energy Efficiency and Conservation (EEC), Water Conservation (WAC), Use of Material Resources and Cycle (MRC), Indoor Health and Comfort (IHC), and Building Environment Management (BEM). These categories align with global GBRSs such as LEED and BREEAM (Surya et al., 2024).

ASD focuses on minimizing environmental disruption through site planning, with indicators include building orientation, accessibility, land remediation, green spaces, and infrastructure alignment. LEED addresses these under Location and Transportation (LT) and Sustainable Sites (SS) (Ismaeel & Elsayed, 2022), while BREEAM emphasize more on pollution control and soil protection during construction (Telichenko et al., 2019).

EEC addresses the optimization of a building's energy performance across its systems. EEC emphasizes efficient energy use across building systems, including envelopes, HVAC, lighting, and power distribution. LEED assesses these elements through the Energy and Atmosphere (EA) category (Pushkar, 2021), while BREEAM highlights performance tracking, metering, and low-carbon sourcing (Pritchard & Kelly, 2017).

WAC supports water efficiency through reliable sourcing, low-consumption fixtures, and reuse systems. LEED's Water Efficiency (WE) category includes indoor and outdoor water strategies (Poon, 2021). BREEAM assesses water use from a broader operational perspective that includes user behaviour (Zegarra, 2021).

MRC encourages reduced material impact through responsible selection, waste prevention, and life cycle thinking. LEED promotes certified materials and transparency in sourcing and embodied carbon (Zegarra, 2021). BREEAM expands this by rewarding efficient design, reuse, and supply chain oversight (Shukla et al., 2015).

IHC addresses occupant health and comfort through air quality, thermal performance, and refrigerant safety. LEED captures these under Indoor Environmental Quality (EQ) and emphasizes measurable indicators such as ventilation and lighting (Lee & Kim, 2008). BREEAM includes additional factors such as ergonomics and access to views, with both systems emphasize the importance of using non-toxic and well-commissioned systems (United States Green Building Council, 2021).

BEM encompasses waste and wastewater management. Indicators include the 3R principles, monitoring systems, and on-site treatment. LEED promotes construction waste diversion and landfill reduction (Chi et al., 2020), while BREEAM stresses end-use waste and water recovery infrastructure (Luangcharoenrat & Intrachooto, 2018).

3. METHODS

This study was structured around two research objectives and conducted in two stages, each involving different data collection and analysis approaches.

3.1 IDENTIFICATION OF GREEN BUILDING CRITERIA

To address the first objective, data were sourced from Indonesia's Regulation of the Minister of Public Works and Public Housing No. 21 of 2021 on Green Building Performance Assessment and from previous studies related to GB certification and BIM applications. Data collection was conducted through document analysis and a literature study. Relevant criteria were extracted and grouped under categories such as site management, energy efficiency, water conservation, and others. These criteria were examined using content analysis to determine their structure and assess whether they matched the characteristics of information stored and processed within BIM models.

3.2 CLASSIFICATION OF BIM-COMPATIBLE CRITERIA

The second objective was addressed through expert validation. Five experts participated in the study, including a BIM consultant, two BIM practitioners, one government regulator, and one academic researcher. All were selected based on their professional experience in BIM implementation and GB evaluation. Data were collected through structured interviews using a validation form that listed all criteria identified in the first stage. Experts assessed whether each criterion could be integrated into BIM or required manual input. Closed-ended questions were used to maintain consistency and clarity throughout the process (Creswell, 2018; Woodhead & Berawi, 2008).

4. RESULTS AND DISCUSSION

4.1 IDENTIFICATION OF GREEN BUILDING CRITERIA

This subsection addresses the first research objective: identifying GB assessment criteria from Indonesia's Regulation of the Minister of Public Works and Public Housing No. 21 of 2021 on Green Building Performance Assessment that align with BIM functionalities. The analysis was conducted by extracting criteria from the regulation and organizing them into six main categories (Kamath et al., 2019; Wardhana et al., 2023).

Each criterion was examined through document analysis and supported by a literature review to determine its alignment with data types and modelling outputs typically found in BIM environments. Prior studies such as Akhanova et al. (2021), Jalaei & Jrade (2014), and Alwan et al. (2015) served as key references in associating regulatory requirements with BIM functionalities, including parametric modelling, spatial coordination, energy simulation, and material tracking.

The result of this process is summarized in Table 1, which lists 29 GB criteria drawn from the regulation along with relevant references that indicate prior studies that support the technical feasibility of assessing each criterion using BIM. These sources were used to validate the relevance of each criterion to BIM functionalities such as modelling, simulation, or automated data extraction. These criteria form the foundation for the classification of BIM compatibility.

Table 1: Green building assessment criteria identified from national regulation

Category		Criteria	References
1. ASD	1.1	Building Orientation	Alwan et al. (2015)
	1.2	Site management including accessibility or circulation	Jalaei & Jrade (2014), Seyis et al. (2021), Akhanova et al. (2021)
	1.3	Management of land contaminated with hazardous & toxic waste (B3)	Akhanova et al. (2021)
	1.4	Private green open space plan	Akhanova et al. (2021), Seyis et al. (2021)
	1.5	Provision of walkways	Akhanova et al. (2021)
	1.6	Basement tread management	
	1.7	Parking Lot Provision	Jalaei & Jrade (2014)
	1.8	Outdoor lighting system	
	1.9	Construction of Building above and/or under Land, Water, and/or Public Infrastructure/Supplies	Akhanova et al. (2021)
2. EEC	2.1	Building envelope	Xu & He (2019), Fan et al. (2023)
	2.2	Ventilation system	Seyis et al. (2021)
	2.3	Air conditioning system	Xu & He (2019), Fan et al. (2023)
	2.4	Lighting system	Jalaei & Jrade (2014), Akhanova et al. (2021)
	2.5	Transportation System in Building	Jalaei & Jrade (2014)
	2.6	Energy efficiency calculation	Seyis et al. (2021)
	2.7	Electrical system	Jalaei & Jrade (2014), Alwan et al. (2015)
3. WAC	3.1	Water Source	Jalaei & Jrade (2014), Seyis et al. (2021)
	3.2	Water usage	
	3.3	Use of water efficiency sanitary equipment	
4. IHC	4.1	Smoking Ban	Jalaei & Jrade (2014)
	4.2	Carbon dioxide (CO_2) and carbon monoxide (CO) control	Jalaei & Jrade (2014), Alwan et al. (2015)
	4.3	Refrigerant Usage Control	Akhanova et al. (2021)
5. MRC	5.1	Controlling the Use of Hazardous Materials	Alwan et al. (2015), Jalaei & Jrade (2014), Seyis et al. (2021)
	5.2	Use of Eco - Labelling Certified Materials	

Category		Criteria	References
6. BEM	6.1	Application of the 3R Principle (Reduce, Reuse, Recycle)	
	6.2	Implementation of Waste Management System	Olanrewaju et al. (2022)
	6.3	Implementation of Waste Generation Recording System	
	6.4	Provision of Wastewater Treatment Facilities Before Discharge to City Sewers	Jalaei & Jrade (2014)

4.2 CLASSIFICATION OF CRITERIA BASED ON BIM COMPATIBILITY

This subsection presents the results of the second research objective, which aims to classify the identified GB criteria based on their compatibility with BIM. The classification was carried out through expert validation using a structured form that listed all 29 criteria extracted from Indonesia's Regulation of the Minister of Public Works and Public Housing No. 21 of 2021 on Green Building Performance Assessment. Five experts that participated in the validation process each had over ten years of professional experience in GB certification or BIM implementation.

The experts assessed whether each criterion could be evaluated using BIM authoring tools or whether manual assessment was necessary. The instrument included binary response options (BIM-based / Manual) and provided space for additional comments. Responses were analyzed to identify which criteria aligned with quantifiable or spatial parameters available in BIM environments, like Autodesk Revit or Green Building Studio (GBS).

The results confirmed that 18 criteria could be evaluated using BIM. These criteria correspond to parameters that can be modelled, simulated, or extracted from BIM platforms. For example, building orientation and lighting systems can be assessed through spatial modelling and daylight simulation, while energy systems such as HVAC and electrical loads are compatible with BIM-integrated performance tools.

CO_2 and CO control can be addressed through space scheduling and pollutant tracking features in Autodesk Revit, which allow simulation of indoor air exchange and monitoring of emissions based on room occupancy and mechanical system configurations (Akhanova et al., 2021). Lighting systems are assessable through daylight simulation and artificial lighting analysis, where BIM tools simulate natural light penetration and optimize lighting layout in accordance with building codes and sustainability standards Jalaei & Jrade (2014). Ventilation and HVAC systems can be modelled using tools such as GBS, which supports airflow simulation, thermal zoning, and mechanical load distribution for performance evaluation.

Energy efficiency calculations are also supported by BIM through dashboards that simulate building energy use and estimate contributions from renewable sources. For water use efficiency, BIM enables water consumption modelling and plumbing fixture representation to estimate total demand and potential savings. Lastly, environmentally friendly materials can be managed in BIM through tagging, quantity take-off, and data exports that support verification of material sources and compliance with eco-labelling or low-impact material requirements (Alwan et al., 2015; Seyis et al., 2021).

The remaining 11 criteria require manual evaluation due to the absence of direct digital representation in BIM or because they involve qualitative elements. These include criteria such as construction above public infrastructure, implementation of waste management systems, and smoking bans. Evaluation of such elements often depends on regulatory interpretation, post-occupancy monitoring, or documentation that must be verified externally. This classification is detailed in Table 3, which categorizes each criterion by its compatibility with BIM-based assessment.

Table 2: Green Building Criteria that can be evaluated using BIM

No.	Category	BIM-integrated		Manual Entry	
1	ASD	1.1	Building Orientation	1.3	Management of land contaminated with hazardous & toxic waste (B3)
		1.2	Site management including accessibility or circulation	1.5	Provision of walkways
		1.4	Private green open space plan	1.7	Parking Lot Provision
		1.6	Basement tread management	1.9	Construction of Building above and/or under Land, Water, and/or Public Infrastructure/Supplies
		1.8	Outdoor lighting system		
2	EEC	2.1	Building envelope		
		2.2	Ventilation system		
		2.3	Air conditioning system		
		2.4	Lighting system		
		2.6	Energy efficiency calculation		
		2.7	Electrical system		
3	WAC	3.1	Water Source		
		3.2	Water usage		
		3.3	Use of water efficiency sanitary equipment		
4	IHC	4.2	Carbon dioxide (CO2) and carbon monoxide (CO) control	4.1	Smoking Ban
		4.3	Refrigerant Usage Control		
5	MRC	5.1	Controlling the Use of Hazardous Materials		
		5.2	Use of Eco – Labelling Certified Materials		
6	BEM			6.1	Application of the 3R Principle (Reduce, Reuse, Recycle)
				6.2	Implementation of Waste Management System
				6.3	Implementation of Waste Generation Recording System
				6.4	Provision of Wastewater Treatment Facilities Before Discharge to City Sewers

The results of this study confirm that BIM can support a substantial portion of Indonesia's GB assessment framework, particularly in categories that rely on quantifiable and spatial data. EEC, WAC, and IHC show high levels of integration with BIM tools and offer strong potential for automation in energy simulation, water efficiency analysis, and indoor environmental monitoring (See Figure 1). In contrast, ASD and MRC include both BIM-integrated and manual-entry criteria, which reflects the need for hybrid approaches in areas involving site-specific design or material documentation. BEM emerges as the least compatible category since all indicators require manual assessment due to their dependence on post-construction operations, waste handling, or regulatory documentation. These findings suggest that while BIM can digitalize sustainability evaluations in many areas, full automation across all GB criteria remains limited.

Integrating BIM into the certification process provides benefits beyond data assessment. BIM centralizes project information, improves visual clarity for reviewers, and reduces duplication in documentation. This allows certification teams to generate compliant submissions more efficiently using model-based outputs. For criteria that cannot be assessed through BIM, supporting materials such as technical reports, annotated plans, or regulatory checklists should be prepared separately and submitted alongside BIM outputs. A hybrid approach that combines digital automation with manual verification ensures that both quantifiable and qualitative criteria are addressed consistently during certification.

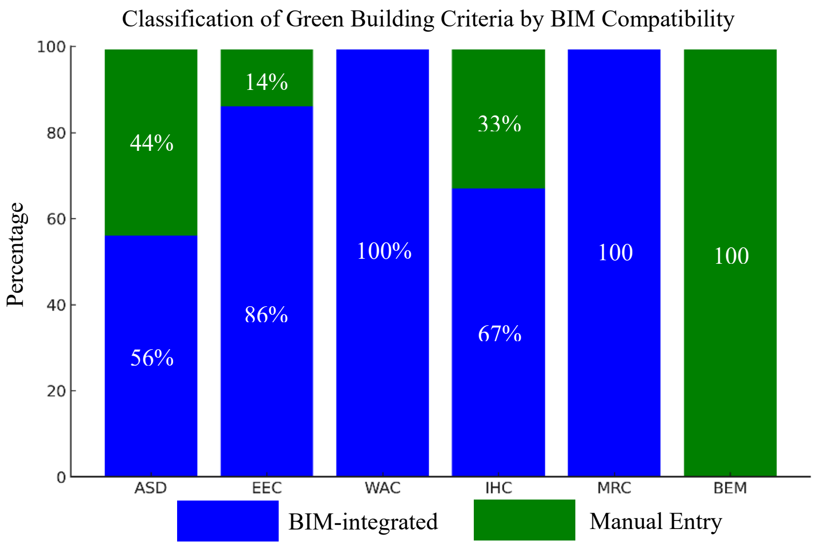

Figure 1: Classification of green building criteria by BIM compatibility

4.3 Comparison with Previous Studies

The findings of this study are consistent with previous research that confirms BIM's ability to support automated assessments across various GBRSs. Prior studies confirm that core criteria, such as EEC, WAC, IHC, ASD, and MRC, are suitable for integration into BIM-based workflows. Lim et al. (2021) introduced a computational BIM workflow built on Dynamo that enabled automation of assessments for EEC, IHC, ASD, and MRC under Malaysia's GBI. Khoshdelnezamiha et al. (2020) created the AGBIA tool, which combined Revit and Dynamo to address five major evaluation categories: EEC, MRC, WAC, IHC, and ASD. Nguyen et al. (2016) enhanced LEED assessments through a BIM-enabled framework that supported multiple green design metrics. Lai et al. (2023) conducted a comprehensive review that showed BIM frequently supports evaluation of

EEC, WAC, ASD, and MRC criteria, especially when integrated with plug-ins or visual scripting tools like Dynamo. Seghier et al. (2017) demonstrated a more technical application by developing a BIM-based method to evaluate ETTV, aligned with energy requirements in the Green Mark and GreenRE certification systems. These studies affirm the results of this research by highlighting BIM's strength in managing quantifiable and performance-driven indicators through modelling and simulation. At the same time, they also identify limitations in BIM's ability to address qualitative or regulation-specific indicators, such as waste management and construction restrictions, which often require manual input or external review.

Although this study focuses on criteria drawn from Indonesia's Regulation No. 21 of 2021, it is necessary to compare these criteria with the rating systems widely used in practice, such as LEED and GBCI. The categories across these systems are broadly similar, particularly in their inclusion of energy, water, materials, and indoor environmental quality. However, the methods of assessment show important differences. The Indonesian regulation primarily adopts a compliance-based structure, where each criterion must be fulfilled in a binary fashion. The Indonesian framework follows a binary compliance model, while LEED and GBCI apply point-based scoring that recognizes partial achievements. This flexibility supports project customization and encourages continuous improvement through higher-level goals.

Beyond structure, international systems often incorporate elements absent from the national regulation. LEED includes innovation credits, lifecycle assessments, and post-occupancy evaluations. These allow project teams to demonstrate ongoing performance, which is not yet part of the Indonesian system. Enhancing the regulation with adaptive scoring and performance monitoring would improve alignment with global practices and strengthen long-term sustainability outcomes.

5. CONCLUSIONS

This study defines a set of green building (GB) assessment criteria based on their potential for integration with Building Information Modelling (BIM). From a total of 29 regulatory criteria outlined in Indonesia's Ministerial Regulation No. 21 of 2021, 18 were identified as suitable for BIM-based evaluation. These include elements that rely on quantifiable data and spatial modelling, particularly in the categories of energy efficiency, water conservation, and indoor health. The remaining 11 criteria require manual assessment due to their qualitative nature or lack of representation in BIM environments.

The main contribution of this study is the development of a regulatory-specific classification framework that links national GB assessment criteria with BIM functionalities. This study offers a localized and practical approach to integrating BIM into Indonesia's sustainability assessment framework. The results provide actionable insights for policymakers, professionals, and stakeholders seeking to adopt digital methods for green building certification.

There are limitations that should be noted. The scope of this study is confined to Indonesia's Regulation No. 21 of 2021 and does not extend to other certification frameworks. Criteria that involve regulatory interpretation, post-construction documentation, or behavioural outcomes remain beyond the current capacity of BIM-based evaluation. Future research should explore ways to address these gaps by integrating BIM with post-occupancy monitoring systems and by comparing the alignment of national GB regulations with BIM across different countries.

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