



ISSN ONLINE: 2447-0228

ITEGAM-JETIA

Manaus, v.12 n.59, p.328-336. May/June, 2026.

DOI: <https://doi.org/10.5935/jetia.v12i59.3439>

RESEARCH ARTICLE

OPEN ACCESS

A CRITICAL REVIEW OF BIM ADOPTION IN DEVELOPING COUNTRIES: INSIGHTS FROM GLOBAL LITERATURE AND INDONESIAN CASE STUDIES

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ARTICLE INFO

Article History

Received: January 27, 2026

Reviewed: March 28, 2026

Accepted: April 28, 2026

Published: May 29, 2026

Keywords:Quantity Take-Off,
Take-Off,
Building Information Modeling,
Indonesia.

ABSTRACT

Building Information Modeling (BIM) adoption in developing countries, particularly Indonesia, is crucial for advancing the construction sector's digital transformation. This study critically reviews existing literature on BIM implementation in Indonesia, focusing on Quantity Take-Off (QTO) and persistent adoption challenges. Utilizing a systematic PRISMA-guided approach and bibliometric analysis, we synthesized fifty key publications. Findings reveal that while BIM offers superior efficiency and accuracy over manual methods, its widespread adoption in Indonesia is hindered by persistent barriers including lack of skilled personnel, high costs, organizational resistance, and inconsistent policy enforcement. This research differentiates itself by critically analyzing why these barriers endure within Indonesia's unique context, moving beyond a descriptive overview. The study maps the current research landscape, linking bibliometric clusters to practical implications for the Indonesian construction industry. It identifies specific limitations and proposes concrete future research directions and policy recommendations for government, academia, and industry stakeholders. The contribution lies in providing a nuanced understanding essential for accelerating BIM's effective integration and unlocking its full potential for the Indonesian construction sector.



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I. INTRODUCTION

The architecture, engineering, and construction (AEC) industry globally is undergoing a profound digital transformation, with Building Information Modeling (BIM) emerging as a cornerstone technology. BIM's capacity to integrate multi-dimensional digital representations of built assets fosters enhanced collaboration, data sharing, and informed decision-making across a project's lifecycle [1], [2]. Globally, the adoption of BIM has yielded significant improvements in cost efficiency, conflict reduction, scheduling accuracy, and sustainability outcomes, aligning with Industry 4.0 paradigms [3-6]. In Indonesia, a nation experiencing rapid urbanization and substantial infrastructure development, the construction sector is a critical economic driver. BIM presents a potential solution to persistent industry challenges such as fragmentation, inefficiencies, and quality control issues [7], [8]. Despite this potential, BIM penetration in Indonesia remains nascent compared to more developed economies [9]. A growing body of research acknowledges BIM's promise for revolutionizing Indonesian construction practices [10]. However, the consistent and widespread adoption of BIM in Indonesia's construction sector is hindered by a range of critical factors, including limited awareness and expertise, high initial investment costs, a lack of comprehensive regulatory frameworks, and organizational resistance to change [3], [11], [12]. While existing literature has documented the benefits, barriers, and technological applications of BIM in Indonesia, a critical gap persists in the articulation of a distinct research novelty and a sharply defined research objective that differentiates this study from prior systematic reviews. Many studies have explored general barriers [3], [8], [13] or focused on specific applications like Quantity Take-Off (QTO) [4], [6], [14].

However, there remains a need for a synthesis that not only reviews the literature but also critically evaluates the persistence of these barriers and explicitly identifies the unique Indonesian context that necessitates tailored solutions, moving beyond generalizable

challenges. Therefore, this study aims to critically synthesize and analyze the existing body of research on BIM adoption and implementation in Indonesia, with a specific focus on understanding the persistent challenges and identifying distinctive contextual factors. This review will differentiate itself from prior works by:

Clearly delineating the specific research gap: While the general barriers to BIM adoption are well-documented, this study will investigate why these barriers remain persistent in Indonesia despite documented initiatives and the unique socio-organizational and policy dynamics at play. The primary objectives are to:

- a. Critically map the thematic landscape of BIM research in Indonesia, identifying key focus areas and trends.
- b. Synthesize the documented benefits and persistent barriers to BIM adoption, with a particular emphasis on the Indonesian context.
- c. Analyze the interplay between technological, educational, policy, and organizational factors contributing to the slow adoption rate.
- d. Identify the limitations of current research and propose clear future research directions to foster more effective and widespread BIM implementation.

By adopting a rigorous methodology that includes PRISMA-compliant article selection and bibliometric analysis, this study seeks to provide a nuanced understanding of BIM's trajectory in Indonesia, offering valuable insights for policymakers, educators, and industry stakeholders striving to accelerate digital transformation within the nation's construction sector.

II. RESEARCH METHODS

This study employs a systematic and critical review methodology to evaluate the adoption and implementation of Building Information Modeling (BIM), with a specific focus on Quantity Take-Off (QTO) practices within the Indonesian construction industry. The approach integrates bibliometric analysis and qualitative synthesis of relevant literature. This methodology is designed to provide comprehensive insights into the comparative advantages of BIM-based QTO over manual methods, the challenges hindering widespread adoption, and to critically address the identified research gap regarding the persistence of these barriers within the Indonesian context.

II.1 LITERATURE SEARCH STRATEGY

The literature search was conducted using the Publish or Perish software to retrieve scholarly articles primarily from Google Scholar. This was complemented by targeted searches within Scopus-indexed journals to ensure academic rigor and the inclusion of peer-reviewed, high-impact sources. This dual-database strategy enhances the breadth and depth of the literature base, aligning with best practices for systematic reviews [1], [2]. The initial search queries combined keywords designed to capture research pertinent to the study's scope: "Building Information Modeling," "BIM," "Quantity Take-Off," "QTO," and "Indonesia." Boolean operators (AND, OR) were used to refine searches and ensure the retrieval of relevant publications. The search was limited to articles published from 2010 to 2025 to capture recent trends and developments in BIM adoption.

II.2 LITERATURE SEARCH STRATEGY

The article selection process strictly adhered to the PRISMA 2020 guidelines to ensure transparency, replicability, and minimize bias [15]. The process involved several stages:

- Identification: Approximately 1,000 documents were initially identified through the database searches.
- Screening: An estimated 200 duplicate records were removed. The remaining documents were screened based on titles and abstracts. Approximately 600 articles were excluded at this stage due to clear irrelevance to BIM, QTO, or the Indonesian context, or because they were identified as non-peer-reviewed materials (e.g., conference abstracts without full papers, opinion pieces).
- Eligibility: Full-text articles of the remaining approximately 200 documents were assessed for eligibility. A further 150 articles were excluded for reasons including:
 - a. Lack of specific focus on BIM adoption or implementation challenges in Indonesia.
 - b. Insufficient detail regarding Quantity Take-Off (QTO) or cost estimation.
 - c. Lack of empirical data or critical analysis relevant to the research questions.
 - d. Inability to access the full text.
- Inclusion: A final selection of 50 documents was included for in-depth review and analysis. These documents represent a robust corpus covering thematic areas such as BIM integration, adoption barriers, cost and time performance, educational initiatives, and policy frameworks pertinent to the Indonesian construction context. The literature search was conducted.

II.3 DATA EXTRACTION AND SYNTHESIS

Data were extracted from the 50 selected articles using a standardized coding framework. The framework captured key information related to study objectives, methodology, findings (particularly regarding BIM vs. manual QTO), identified barriers and drivers, proposed solutions, and the specific context. A qualitative thematic synthesis was employed to analyze the extracted data. This involved:

- Identifying recurring themes: Patterns related to BIM benefits, challenges (technical, financial, organizational, policy-related), successful implementation strategies, and educational needs were identified.

- Comparative analysis: Findings from studies focusing on BIM-based QTO were critically compared with those discussing manual methods, paying close attention to reported metrics on accuracy, efficiency, and error rates [6], [7]. The persistence of manual methods was analyzed by synthesizing literature that explores practitioner perceptions and cost-benefit considerations [4], [12], [16].
- Contextualization: Findings were discussed within the specific socio-economic and regulatory environment of Indonesia, referencing government policies [7], [9] and industry practices.

II.4 BIBLIOMETRIC ANALYSIS

Bibliometric analysis was performed using VOSviewer software [17] on the selected corpus of 50 documents, augmented by the initial wider search results (approximately 1,000 documents) to ensure comprehensive mapping. This analysis aimed to:

- Identify Key Themes and Research Clusters: Keyword co-occurrence mapping was used to visualize the dominant research foci and their interconnections within the Indonesian BIM research landscape (Figure 1).
- Map Research Trends: While not explicitly detailed in a separate visualization in this section, the analysis informed the identification of publication trends over time within the broader search results, contributing to understanding the growth of BIM research in Indonesia.
- Identify Influential Authors and Sources: This further supported the comprehensive understanding of the research field, though specific author productivity analysis is not detailed here.

The bibliometric maps provided a macro-level understanding of the research landscape, which was then integrated with the qualitative thematic synthesis to provide a richer, multi-dimensional perspective on BIM research in Indonesia.

II.5 BIBLIOMETRIC ANALYSIS

This review acknowledges certain limitations. While extensive searches were conducted, the reliance on Google Scholar and specified Scopus journals might exclude relevant publications from other databases or regional sources. The exclusion of non-peer-reviewed grey literature beyond institutional repositories, due to consistency and quality control, may mean some industry-specific insights are not captured. Furthermore, the synthesis is based on secondary data reported in previous studies, and direct engagement with industry practitioners was not undertaken. The bibliometric analysis, while providing valuable overviews, is dependent on the quality and indexing of the source data.

III. RESULTS

III.1 BIBLIOMETRIC ANALYSIS OF BIM RESEARCH IN INDONESIA

The bibliometric analysis, utilizing VOSviewer [17], identified key themes and research trajectories in the Indonesian BIM domain. The co-occurrence mapping of keywords from the comprehensive literature search (approximately 1,000 initial documents) illuminated three major thematic clusters (Figure 1):

- a. Red Cluster: Barriers, Integration, and Policy: This cluster encompasses keywords such as "barrier," "construction industry," "integration," "cost," "time," and "government." It highlights research focused on the obstacles to BIM adoption, performance improvements in terms of cost and time, and the crucial role of governmental policies within Indonesia [3], [7], [8].
- b. Green Cluster: Implementation Specifics in Indonesia: Keywords here include "di Indonesia," "teknologi," "studi kasus," "autodesk revit," and "building information." This cluster reflects studies focusing on the practical application of BIM, specific case studies, and technology adoption within Indonesian projects [6], [9].
- c. Blue Cluster: Broader AEC Context: This cluster comprises terms like "aec," "architecture," and "engineering," contextualizing BIM within the wider architectural, engineering, and construction ecosystem. It supports literature advocating for integrated educational programs and cross-disciplinary skill development [1], [2], [12].

Further bibliometric visualizations, including trend lines of publication volume over time and co-authorship networks, were generated (Figures 2 and 3). Publication trends indicate a steady increase in BIM-related research originating from Indonesia since 2015, with a notable acceleration in the last five years. Co-authorship analysis reveals a core group of active researchers and institutions, suggesting emerging collaborative networks, though significant opportunities exist for broader inter-institutional and international collaborations. The interconnections between these clusters signify that research in Indonesia addresses the technical applications of BIM, the inherent industry challenges, and the necessary policy frameworks, reflecting a multifaceted approach to understanding BIM adoption.

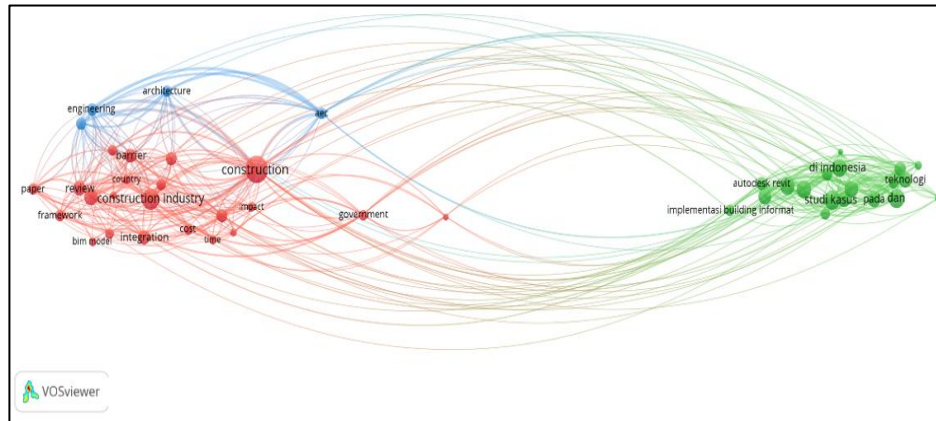


Figure 1: Keyword Co-occurrence Map of BIM Research in Indonesia, showing thematic clusters related to barriers, implementation, and the AEC context (Source: VOSviewer analysis).

Source: Authors, (2026).

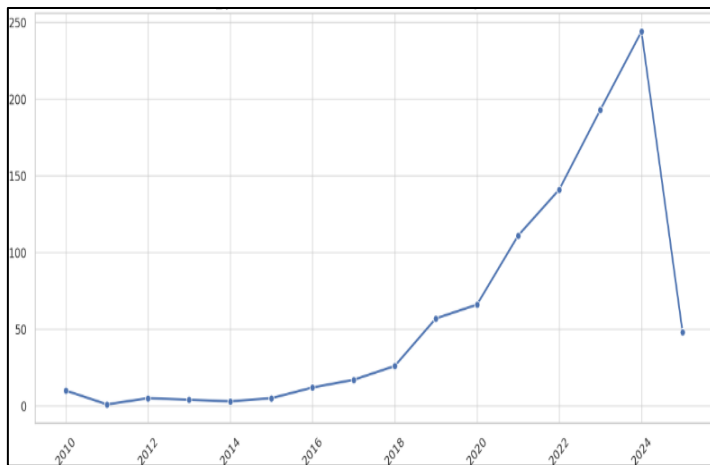


Figure 2: Trend lines of publication.

Source: Authors, (2026).

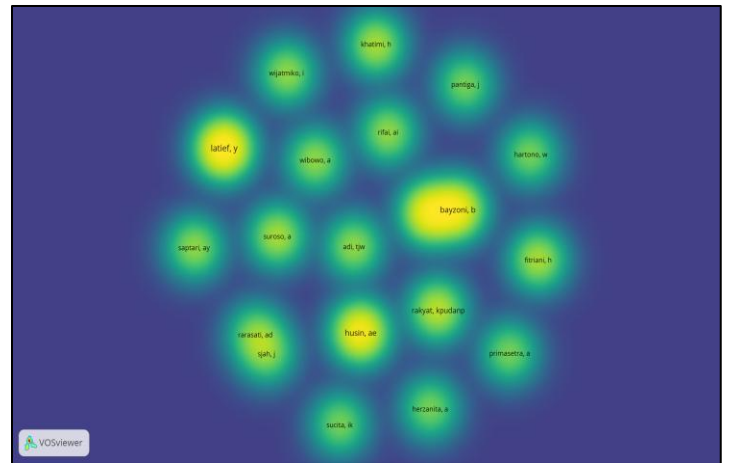


Figure 3: Co-authorship networks (Source: VOSviewer analysis).

Source: Authors, (2026).

III.2 PRISMA FLOW AND STUDY SELECTION

The PRISMA flow diagram (Figure 4) illustrates the systematic article selection process. From an initial corpus of approximately 1,000 documents, rigorous screening based on titles, abstracts, and full-text eligibility resulted in 50 documents for in-depth review. This process, guided by predefined inclusion and exclusion criteria detailed in Section 2.2, ensured a high-quality dataset for analysis. The included studies represent relevant contributions to BIM adoption in Indonesia, covering diverse themes such as technological integration, adoption barriers, performance improvements, educational initiatives, and policy frameworks [3], [6], [7], [10].

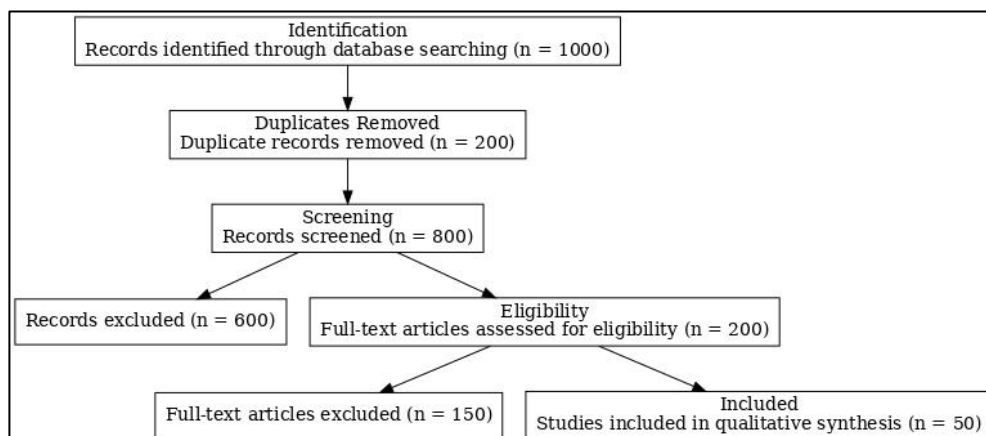


Figure 4: PRISMA Flow Diagram of the Study Selection Process.

Source: Authors, (2026).

III.3 THEMATIC CLUSTERS AND KEY FINDINGS

Thematic synthesis of the 50 selected articles, categorized as presented in Table 1, revealed key findings aligned with the bibliometric clusters:

Table 1: Thematic Clusters and Sample Studies of Selected BIM Research in Indonesia.

Theme	Description	Sample Studies (Authors, Year)	Key Findings Relevant to Indonesian Context
1. BIM Adoption & Implementation	Status, barriers, drivers, and strategies for BIM adoption.	(Saka & Chan, 2020) [3]; (Latief & Hidayat, 2020) [7]; (Husin et al., 2021) [6]; (Wibowo et al., 2023) [9]; (Abdelhameed & Ismaeil, 2024) [1]; (Alghuried, 2023) [2]; (Raitviir, 2024) [3]; (Al-Ruwaishedi et al., 2024) [4]; (Gao et al., 2025) [5]; (Pasha & Mohamad Rasdi, 2022) [6].	Widespread acknowledgement of BIM benefits but significant challenges in practical implementation. Common barriers include lack of skilled personnel, high costs, and insufficient government support/mandates.
2. BIM for Quantity Take-Off & Cost Estimation	BIM-based QTO accuracy, efficiency, and comparison to manual methods.	(Husin et al., 2021) [6]; (Latief & Hidayat, 2020) [7]; (Novita & Pangestuti, 2021) [18]; (Zhang & Mo, 2024) [7]; (Khant et al., 2024) [8]; (Rashidi et al., 2024) [9]; (Fei et al., 2024) [10]; (Cassandro et al., 2024) [11]; (Salahaldain et al., 2023) [12]; (Abdulwahhab et al., 2022) [13]; (Al-Musawi & Naimi, 2023) [14]; (Lu et al., 2023) [15].	BIM-based QTO consistently shows superior accuracy, time efficiency, and reduced human error compared to manual methods. However, manual methods persist due to familiarity and perceived lower complexity for certain project scales.
3. BIM & Emerging Technologies	Integration with GIS, IoT, Blockchain, Digital Twins for enhanced workflows.	(Liu et al., 2017) [10]; (Ding et al., 2019) [11]; (Nawari & Ravindran, 2019) [4]; (Alazawy et al., 2024) [16]; (Park & Yun, 2023) [17]; (Javaherikhah et al., 2025) [19]; (Marcos et al., 2024) [20]; (Xue et al., 2022) [21]; (Lee et al., 2024) [22]; (Song, 2022) [23]; (Yin et al., 2023) [24].	Growing interest in integrating BIM with other digital technologies to enhance transparency, asset management, and data security. However, adoption of these advanced integrations is even more nascent than core BIM in Indonesia.
4. Policy & Institutional Support	Government policies, regulations, and institutional frameworks promoting BIM.	(Latief & Hidayat, 2020) [7]; (Wibowo et al., 2023) [9]; (Rahmani & Herumanta, 2023) [25]; (Ali et al., 2024) [26]; (Kim et al., 2025) [18].	Government initiatives exist (e.g., Ministry Regulation No. 22/PRT/M/2018), but enforcement and industry-wide compliance remain inconsistent. Policy frameworks need strengthening and better alignment with industry capacity.
5. Education & Capacity Building	BIM education, training programs, competency development, and curriculum alignment.	(Husin et al., 2021) [6]; (Saka & Chan, 2020) [3]; (Gegana & Widjanarso, 2015) [16]; (Soon et al., 2024) [25]*; (Diaz Schery et al., 2023) [27].	A critical knowledge gap exists between academic BIM curricula and industry demands. Insufficient hands-on training and a lack of qualified BIM educators are significant constraints.
6. Technological Innovation & Applications	BIM applications in safety, scheduling, sustainable design, and energy efficiency.	(Eastman et al., 2017) [22]; (Kim et al., 2024) [23]; (Nguyen et al., 2024) [26]; (Rocha & Mateus, 2024) [28]; (Yang et al., 2025) [29]; (Ibrahimkhil et al., 2023) [30]; (Liu et al., 2024) [31]; (Fang et al., 2025) [32]; (Ikeda & Yabuki, 2023) [33].	While global research explores advanced BIM applications, their implementation in Indonesia is limited, often confined to large-scale projects or specific firms. Focus remains on foundational BIM use. Furthermore, advanced BIM-based clash detection prioritization techniques have been proposed to enhance design-phase coordination efficiency and reduce downstream construction conflicts [34].
7. Barriers & Challenges	Technical, financial, organizational, and cultural barriers to BIM adoption.	(Saka & Chan, 2020) [3]; (Waqar et al., 2023) [8]; (Aziz et al., 2016) [7]; (Wibowo et al., 2023) [9]; (De Wolf et al., 2023) [35]; (Waqar et al., 2024) [36]; (Hasan et al., 2023) [37]; (Nsimbe & Di, 2024) [38].	Persistent barriers include: (1) human resource readiness; (2) financial constraints affecting SMEs [2], [8], [32]; (3) organizational resistance and limited leadership commitment [3],[9], [30]; (4) uneven technological infrastructure; and (5) regulatory inconsistencies requiring standardized BIM protocols [7], [9]. Limited access to reliable digital infrastructure in some regions [8]. 5. Policy and Regulatory Gaps: Inconsistent enforcement of existing regulations and a need for standardized BIM protocols [7], [9].

Source: Authors, (2026).

III.4 LINKING KEYWORD CLUSTERS TO PRACTICAL IMPLICATIONS FOR INDONESIA

The bibliometric keyword clusters provide direct insights into practical implications for the Indonesian construction industry:

- a. Red Cluster Insights: The strong presence of "barrier," "cost," and "government" underscores the urgent need for targeted policy interventions and financial support mechanisms from government bodies to facilitate BIM adoption, especially for SMEs [2], [8], [19]. Strategies must address not only technological adoption but also regulatory frameworks and enforcement.

- b. Green Cluster Insights: The focus on "studi kasus" and specific technologies like "Autodesk Revit" highlights the importance of disseminating successful Indonesian case studies and promoting accessible training pathways. Practical implications involve developing industry-specific BIM implementation roadmaps and fostering knowledge sharing among practitioners.
- c. Blue Cluster Insights: The connection to "AEC" and "architecture/engineering" emphasizes that practical implications must consider cross-disciplinary integration. This points to the need for multi-stakeholder collaboration and the alignment of BIM education across academic disciplines to prepare a holistic AEC workforce.

These explicit links suggest that research discoveries directly inform actionable strategies for industry stakeholders, moving beyond theoretical discussions to practical implementation guidance tailored to Indonesia.

IV. DISCUSSIONS

This study has critically analyzed the landscape of Building Information Modeling (BIM) adoption and implementation within Indonesia's construction sector, providing a synthesis of existing research and bibliometric insights. The findings underscore that while BIM offers significant advantages in enhancing project accuracy, efficiency, and collaboration particularly in Quantity Take-Off (QTO) processes its adoption in Indonesia is impeded by a complex interplay of persistent barriers. These include limited technical expertise, substantial financial costs, organizational resistance, inadequate technological infrastructure, and inconsistent policy enforcement. The research confirms the relevance of BIM as a transformative technology for developing countries, contributing theoretically by mapping specific research trends in Indonesia and practically by identifying actionable insights for industry stakeholders. By rigorously synthesizing the literature through PRISMA-compliant methods [15] and bibliometric analysis [17], this study moves beyond a purely descriptive account to critically evaluate why these barriers endure within the Indonesian context, differentiating it from prior reviews and offering a deeper understanding informed by the specific socio-economic and regulatory dynamics of the nation [7], [9].

IV.1 LINKING KEYWORD CLUSTERS TO PRACTICAL IMPLICATIONS FOR INDONESIA

The analysis highlights that despite documented benefits [6], [7], the persistent challenges related to human resource readiness, financial constraints (especially for SMEs [2], [8], [19]), organizational culture [3], [9], [30], and policy implementation gaps [7], [9] require more than generic solutions. The Indonesian context necessitates tailored strategies that acknowledge its unique market structure and regulatory environment. The study emphasizes that the continued reliance on manual QTO methods, while familiar, hinders the sector's progress towards greater efficiency and accuracy, underscoring the need for a deliberate transition pathway [6], [9], [16].

IV.2 POLICY AND PRACTICAL RECOMMENDATIONS

To accelerate BIM adoption and overcome the identified persistent barriers, this study proposes the following actionable recommendations:

1. For the Indonesian Government:
 - a. Strengthen and Enforce BIM Mandates: Move beyond policy statements to robust enforcement mechanisms for BIM in public projects, coupled with clear guidelines and technical standards.
 - b. Financial Incentives and Support Programs: Introduce targeted subsidies, tax incentives, or low-interest loan programs specifically for SMEs to offset the initial costs of BIM adoption.
 - c. National BIM Roadmap Development: Establish a national, coordinated roadmap with clear timelines, targets, and responsible agencies for BIM implementation across the AEC sector.
 - d. Promote Interoperability Standards: Facilitate the adoption of open BIM standards to ensure seamless data exchange and reduce vendor lock-in.
2. For Academia and Educational Institutions:
 - a. Curriculum Reform: Integrate practical, hands-on BIM training into undergraduate and postgraduate curricula across architecture, engineering, and construction disciplines.
 - b. Develop Certified BIM Professional Programs: Establish accredited training and certification programs to address the shortage of skilled BIM professionals.
 - c. Foster Industry-Academia Collaboration: Promote research partnerships, internships, and joint development projects to bridge the gap between academic knowledge and industry needs.
3. For the Construction Industry:
 - a. Invest in Capacity Building: Prioritize continuous professional development and upskilling for existing staff in BIM technologies and workflows.
 - b. Embrace Change Management: Develop strategies to foster a culture of innovation, encourage leadership commitment, and effectively manage organizational resistance to BIM adoption.
 - c. Promote Collaborative BIM Workflows: Encourage the adoption of collaborative platforms and practices to enhance stakeholder communication and data sharing.
 - d. Explore Phased or Hybrid Adoption: For SMEs, consider phased implementation strategies or hybrid workflows that integrate BIM gradually with existing manual processes to manage costs and build confidence.

IV.3 LIMITATIONS AND FUTURE RESEARCH DIRECTIONS

This study acknowledges its limitations, as detailed in Section 2.5, including reliance on secondary data, exclusion of certain grey literature, and the scope of databases searched. These limitations suggest avenues for future research:

1. Longitudinal Impact Studies: Conduct empirical, longitudinal studies to quantitatively measure the sustained impact of BIM adoption on project performance (cost, time, quality, safety) in Indonesia.
2. Deep-Dive into SME Adoption: Undertake in-depth case studies focusing specifically on the challenges and successful strategies for BIM adoption within Indonesian SMEs.
3. Comparative Analysis with Other Developing Countries: Expand the comparative discussion to systematically analyze how specific contextual factors in Indonesia differentiate its BIM adoption trajectory from other developing nations.
4. Impact of Emerging Technologies: Investigate the adoption readiness and potential impact of integrating BIM with other digital technologies (IoT, AI, Blockchain) within the Indonesian context.
5. Socio-Organizational Dynamics: Further explore the cultural and social aspects influencing BIM adoption, including stakeholder perceptions, trust, and collaboration dynamics.

By addressing these recommendations and future research directions, stakeholders can work towards a more coordinated and effective approach to BIM adoption, ultimately driving digital transformation and enhancing the competitiveness and sustainability of Indonesia's construction industry.

V. CONCLUSIONS

This study critically reviewed the adoption and implementation of Building Information Modeling (BIM) in the Indonesian construction industry, highlighting persistent challenges and unique contextual factors. By integrating bibliometric analysis with a deep thematic synthesis of 50 selected scholarly articles, this research provides a nuanced understanding of BIM's trajectory in Indonesia, moving beyond mere description to analyze why adoption lags persist. The primary findings underscore that while BIM offers significant global advantages in accuracy, efficiency, and collaboration, particularly for Quantity Take-Off (QTO), its uptake in Indonesia is hampered by a complex interplay of enduring barriers. These include a critical shortage of skilled personnel, substantial financial constraints affecting SMEs, deep-seated organizational resistance to change, underdeveloped technological infrastructure, and inconsistent policy enforcement. Crucially, this study emphasizes that these barriers are not merely generic challenges faced by developing countries but are perpetuated by specific Indonesian socio-economic, regulatory, and cultural dynamics. The contribution of this research lies in its critical evaluation of why these barriers remain entrenched despite existing initiatives, offering a more profound insight than previous reviews. It addresses the core research questions by identifying the specific Indonesian context that shapes these persistent adoption challenges and differentiates them from broader global trends. The study's implications are practical: it highlights that successful BIM integration necessitates tailored strategies addressing not just technological implementation but also systemic issues like policy enforcement, targeted financial support for SMEs, and robust, industry-aligned capacity building. Based on these findings, strong policy and research recommendations are proposed:

- For the Indonesian Government: Develop and rigorously enforce BIM mandates with clear implementation roadmaps, provide targeted financial incentives (e.g., subsidies for SMEs), and establish national BIM standards to ensure interoperability and consistency.
- For Academia: Revise BIM curricula to bridge the gap between theoretical knowledge and practical industry needs, increase hands-on training, and foster research into context-specific BIM solutions.
- For Industry: Embrace BIM through strategic leadership commitment, invest in continuous training and upskilling of personnel, and foster collaboration across firms to share best practices and mitigate costs.

Limitations include reliance on secondary data and the exclusion of some grey literature. Future research should focus on longitudinal studies to assess BIM's sustained impact, conduct direct empirical investigations into SME challenges, explore the effectiveness of hybrid BIM-manual workflows, and investigate the potential of emerging technologies integrated with BIM within the Indonesian context. This study provides a foundational analysis, paving the way for more targeted interventions advancing digital transformation in Indonesia's construction sector.

VI. AUTHOR'S CONTRIBUTION

Conceptualization: Fendi Hary Yanto, Widi Hartono and Taufiq Lilo Adi Sucipto.

Methodology: Fendi Hary Yanto and Taufiq Lilo Adi Sucipto.

Investigation: Fendi Hary Yanto.

Discussion of results: Fendi Hary Yanto, Widi Hartono and Taufiq Lilo Adi Sucipto.

Writing – Original Draft: Fendi Hary Yanto.

Writing – Review and Editing: Fendi Hary Yanto.

Resources: Fendi Hary Yanto..

Supervision: Widi Hartono and Taufiq Lilo Adi Sucipto.

Approval of the final text: Fendi Hary Yanto.

VII. ACKNOWLEDGMENTS

The authors gratefully acknowledge the financial support provided under Grant No. 196/UN27/TM.00.07/2024, which significantly contributed to the completion of this study. This research was also supported by LPPM Universitas Sebelas Maret (UNS) through research grants under Contract No. 371/UN27.22/xxxxx/2026 for the projects entitled:

(1) “Development of a Mathematical BIM-QTO Correction Model Based on Fuzzy AHP for Harmonizing Quantity Deviations in Construction Projects”, and

(2) “Pengaruh Variasi Substitusi Limbah Cangkang Kerang terhadap Sifat Mekanis Paving Block sebagai Inovasi di Bidang Teknik dan Rekayasa Konstruksi Bangunan Gedung.”

The authors sincerely appreciate the institutional and financial support that made this research possible.

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