



Systematic Literature Review on Building Information Modeling (BIM) Implementation in Construction Projects: Trends, Challenges, and Future Directions

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Abstract

Digital transformation in the construction industry is driving the adoption of Building Information Modeling (BIM) to support information integration and project management. This study aims to analyze development trends, implementation challenges, research gaps, and future directions for BIM in construction projects. The method used was a Systematic Literature Review (SLR) with data sourced from Scopus for the period January 2021–May 2026. A total of 647 articles were used in the bibliometric analysis using VOSviewer and the bibliometrix package in RStudio, while 50 articles were analyzed in a qualitative synthesis based on the literature selection process. The analysis identified seven research clusters: project management, sustainability, cost estimation, semantics and interoperability, BIM adoption and education, safety and risk, and civil infrastructure. This study also applied Value Stream Mapping (VSM) conceptually to identify eight categories of waste in BIM-based information flows. The study's results indicate an increasing interconnection between BIM research and Artificial Intelligence (AI), Digital Twins, and the Internet of Things (IoT). Research gaps primarily relate to the context of developing countries, particularly Indonesia and Southeast Asia, as well as the integration of BIM with lean construction principles. Based on these findings, this study proposes a BIM development roadmap for 2026–2030 that considers the needs and constraints of the construction sector in developing countries.

Keywords: building information modeling; construction projects; systematic literature review; bibliometric analysis; value stream mapping.

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INTRODUCTION

The construction industry is undergoing a digital transformation driven by the need to improve project efficiency, information accuracy, productivity, and coordination among project stakeholders [1], [2]. One of the key technologies supporting this transformation is Building Information Modeling (BIM), which enables the creation, management, and exchange of project

information through a coordinated digital model [3], [4]. BIM supports several construction activities, including multidisciplinary coordination, project visualization, quantity take-off, clash detection, cost estimation, and project management [2], [5]–[7]. These capabilities have increased interest in BIM as a means of improving information integration and supporting decision-making throughout the construction project lifecycle.

Despite its potential benefits, BIM implementation continues to face several challenges. Previous studies have identified barriers related to the availability of skilled personnel, implementation costs, hardware and software requirements, resistance to organizational change, and the absence of standardized working practices [11], [12]. In addition, the development of Artificial Intelligence (AI), Digital Twin, and Internet of Things (IoT) technologies has created new opportunities for integrating BIM with automated analysis, real-time monitoring, and digital construction management [8]–[10]. However, the availability of these technologies does not automatically ensure successful implementation. Their practical application depends on organizational readiness, information management practices, technical interoperability, and the capacity of construction stakeholders to adopt digital workflows.

Previous research has examined BIM from various perspectives, including project management, sustainability, cost engineering, information integration, safety, education, and civil infrastructure [2], [6]–[10]. Nevertheless, a clearer synthesis is needed to understand how these research themes have developed, which implementation challenges remain prominent, and where future research should be directed. In particular, the integration of bibliometric mapping and qualitative literature synthesis can provide complementary insights into the structure of the research field and the substantive findings reported in individual studies. Furthermore, a conceptual Value Stream Mapping (VSM) perspective may help examine information flows and potential sources of waste in BIM-enabled construction workflows. This perspective should be understood as a conceptual analytical approach rather than an empirically validated representation of every construction project.

Another important consideration is the contextual applicability of BIM research. Findings and implementation approaches developed in countries with established digital construction practices may not be directly transferable to developing countries, where organizational capacity, digital infrastructure, professional competencies, and regulatory

conditions may differ [12]–[15]. Indonesia and other Southeast Asian countries therefore represent relevant contexts for further investigation. The relationship between BIM and lean construction also requires continued attention, particularly in understanding how information flow, collaboration, and digital coordination can support the reduction of inefficiencies in construction processes [14], [15].

Based on these considerations, this study examines BIM implementation in construction projects through an integrated approach combining systematic literature review (SLR), bibliometric analysis, and a conceptual VSM framework. The study uses 647 Scopus-indexed articles published between January 2021 and May 2026 for bibliometric analysis, while 50 selected articles are included in the qualitative synthesis, according to the reported literature-selection procedure. Specifically, this study aims to: (1) identify the principal research themes and development trends in BIM implementation; (2) synthesize the implementation challenges and research gaps reported in the selected literature; (3) conceptually map information flows and identify eight categories of potential waste in BIM-enabled construction workflows; and (4) propose a contextual research roadmap for 2026–2030, with particular attention to developing countries, including Indonesia. By combining these perspectives, the study seeks to provide a structured overview of BIM research and identify directions for future investigation and practical development.

METHOD

2.1 Data Source

This study employed a Systematic Literature Review (SLR) combined with bibliometric analysis and a conceptual Value Stream Mapping (VSM) approach to examine research trends, implementation challenges, and future directions of Building Information Modeling (BIM) in construction projects. Scopus was selected as the sole bibliographic database because it provides broad coverage of peer-reviewed scientific publications and structured metadata suitable for bibliometric analysis. The literature search covered journal articles

published in English from January 2021 through May 2026.

The bibliographic records were retrieved from Scopus and exported in RIS format on 9 May 2026. The exported metadata included article titles, authors, publication sources, publication years, abstracts, keywords, and available bibliographic information. These records were subsequently processed for duplicate identification, data cleaning, bibliometric mapping, and literature screening. The initial Scopus search returned 2,817 records before duplicate removal and subsequent screening.

2.2 Search Strategy

The literature search was conducted using a combination of keywords related to BIM and construction projects. Boolean operators were applied to retrieve publications containing the relevant terms in their titles, abstracts, or keywords. The Scopus search query is presented in Table 1.

Table 1. Scopus Search Query

No	Keywords / Queries	Number of Articles
1.	TITLE-ABS-KEY ("BIM" OR "Building Information Modeling") AND TITLE-ABS-KEY ("construction project" OR "construction management") AND PUBYEAR > 2020	2,817

Source: Scopus

The search was restricted to English-language journal articles published from 2021 through the retrieval date in May 2026. The initial search yielded 2,817 records. These records were then subjected to duplicate removal, title and abstract screening, and full-text eligibility assessment. The search strategy was designed to identify literature relevant to BIM implementation in construction projects, including research addressing project management, sustainability, cost estimation, information integration, education, safety, and civil infrastructure.

Table 2. Most Productive Journals in the Dataset

Journal Name	Number of Articles	Percentage (%)
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Buildings	89	13.8%
Applied Mathematics and Nonlinear Sciences	52	8.0%
Automation in Construction	38	5.9%
Construction Innovation	31	4.8%
Journal of Construction Engineering and Management	28	4.3%
Smart and Sustainable Built Environment	24	3.7%
Civil Engineering and Architecture	21	3.2%
Advances in Civil Engineering	19	2.9%
Journal of Information Technology in Construction	17	2.6%
Other journals	328	50.7%
Total	647	100%

Source: Scopus

Table 2 presents the distribution of publications across the most productive journals in the dataset. *Buildings* contributed the largest number of articles, with 89 publications (13.8%), followed by *Applied Mathematics and Nonlinear Sciences* with 52 articles (8.0%) and *Automation in Construction* with 38 articles (5.9%). The remaining publications were distributed across other journals, which collectively accounted for 328 articles (50.7%). This distribution indicates that the literature on BIM implementation examined in this study is dispersed across multiple publication outlets rather than concentrated exclusively in the leading journals. The journal counts and percentages were calculated based on the total dataset of 647 articles.

2.3 Data Analysis

Three complementary analytical techniques were employed in this study.

First, bibliometric analysis was conducted using VOSviewer and the bibliometrix package in RStudio. VOSviewer was used to examine keyword co-occurrence and visualize relationships among major research topics. The analysis used a minimum keyword occurrence threshold of two to construct the keyword network. The bibliometrix package was used to support the examination of publication trends and thematic development across the study period. A total of 647 Scopus-indexed articles formed the bibliometric dataset.

Second, qualitative content synthesis was conducted on 50 articles retained after the literature selection process. The selected articles were examined to identify recurring themes, reported implementation challenges, research gaps, and potential directions for future BIM development. The synthesis was organized around the major research themes identified in the bibliometric analysis and the study objectives.

Third, a conceptual VSM approach was used to examine information flows in BIM-enabled construction workflows. The analysis considered potential sources of information-related waste and organized them into eight categories, as presented in the results section. A conceptual future-state workflow was then developed around the potential roles of a Common Data Environment (CDE), BIM–Digital Twin integration, and Industry Foundation Classes (IFC) standards in supporting information coordination and interoperability. This VSM component was developed as a conceptual analytical framework based on the literature and was not empirically validated through direct observation of a construction project.

The findings from bibliometric analysis, qualitative synthesis, and conceptual VSM were compared to establish connections between research trends, implementation challenges, and potential improvement strategies. This combined approach provided the basis for developing a contextual research roadmap for BIM implementation during 2026–2030, with particular attention to developing countries, including Indonesia.

2.4 Systematic Literature Review Procedure

The literature selection process followed the four main stages of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework: identification, screening, eligibility, and inclusion [18].

During the identification stage, the Scopus search retrieved 2,817 records. A total of 1,320 duplicate records were removed, leaving 1,497 records for screening. During the screening stage, titles and abstracts were examined for relevance to the research scope, resulting in the exclusion of 850 records. The remaining 647 articles were retained for bibliometric analysis and further eligibility assessment.

During the eligibility stage, the full-text relevance of the 647 articles was assessed against the study scope. A further 597 articles were excluded for the following reported reasons: 250 articles were not sufficiently relevant to BIM implementation, 180 did not address construction management within the intended scope, and 167 had insufficient data or fell outside the scope of the review. Following these exclusions, 50 articles were retained for qualitative synthesis.

The resulting datasets served different analytical purposes: the 647 articles were used to map the broader bibliometric structure of BIM research, whereas the 50 selected articles were used for qualitative synthesis. The selection process is summarized in Figure 1 using the PRISMA flow diagram.

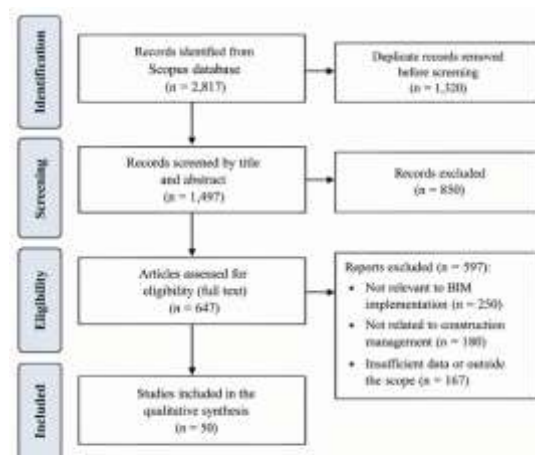


Figure 1. PRISMA-based flow diagram of the literature selection process.

Figure 1. PRISMA-based flow diagram of the literature selection process.

RESULTS AND DISCUSSION

3.1 Keyword Co-occurrence Analysis

Keyword co-occurrence analysis was conducted using VOSviewer version 1.6.20 based on the bibliographic records of 647 Scopus-indexed articles [16]. A minimum occurrence threshold of two was applied to identify frequently occurring keywords and examine the relationships among research topics. The resulting network visualization is presented in (Figure 2).

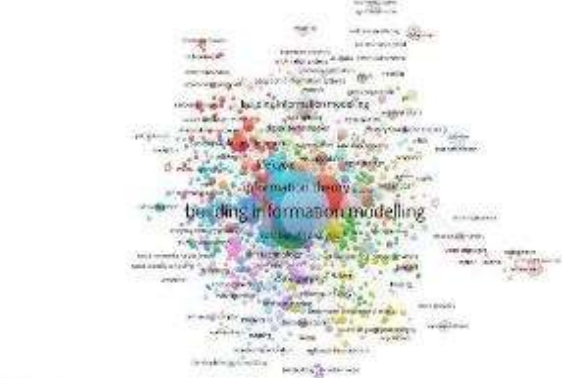


Figure 2. Keyword co-occurrence network (network visualization)
Source: VOSviewer application (version 1.6.20), 2026

Figure 2 reveals seven main clusters, summarized in Table 3.

Table 3. Thematic Clusters of BIM Research from the VOSviewer Analysis

No	Cluster	Representative Keywords	Key References
1	Project Management BIM (Red)	building information modelling, construction project management, life cycle, project success, cost-efficiency	[2], [13], [19]
2	Sustainability and Digital Technologies (Green)	Digital technologies, sustainable development, visualization, carbon emissions, environmental impact	[20], [22]

3	5D Estimation (Blue)	cost benefit analysis, cost engineering, cost estimating	[3], [7], [23]
4	Semantics & Interoperability (Yellow)	semantics, industry foundation classes (IFC), digital twin, database, robotics	[9], [24], [25]
5	BIM Adoption & Education (Purple)	bim adoption, maturity model, students, teaching, construction education	[4], [12], [26]
6	Safety & Risk (Orange)	risk management, clash detection, automated compliance checking, 4D BIM, safety	[10], [19], [27]
7	Civil Infrastructure (Brown)	bridges, tunnels, prestressed materials, computer vision, structural dynamics	[8], [28]

Source: VOSviewer

Among the keywords displayed in the network, “building information modelling” appears as the largest node, followed by “cost-benefit analysis,” “information theory,” “life cycle,” “sustainable development,” and “digital technologies.” In VOSviewer network visualization, node size represents the occurrence frequency of a keyword, whereas links indicate co-occurrence relationships between keywords. The strength of these relationships is reflected in the links and their associated weights. The prominence of “building information modelling” indicates its central role in the analyzed dataset. The interconnectedness of keywords related to project management, cost analysis, and life-cycle considerations further illustrates the relationship between BIM and construction project management research [2], [19].

The temporal distribution of keywords provides additional insight into the development of BIM research during the study period. The manuscript's overlay visualization indicates the presence of topics associated with digital twin, machine learning, augmented reality, and artificial intelligence. These topics suggest growing research interest in integrating BIM with data-driven analysis, digital representation, and advanced visualization technologies. However, the magnitude of growth for individual keywords should be established through annual publication counts before specific percentage increases are reported.

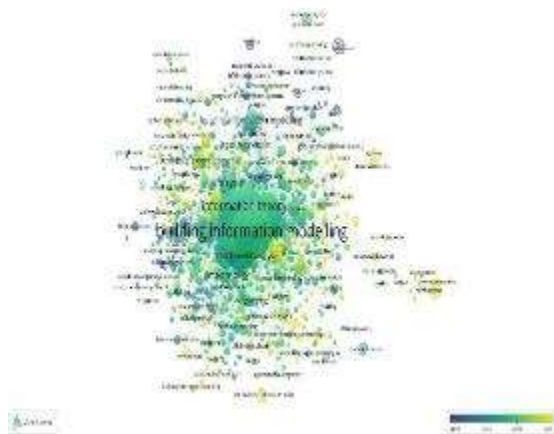


Figure 3. Keyword co-occurrence (overlay visualization)

The overlay visualization in Figure 3 represents keywords according to their average publication year, as indicated by the VOSviewer color scale. Keywords with earlier average publication years appear toward the older end of the scale, whereas keywords with more recent average publication years appear toward the newer end. The map places core BIM-related terms in relation to topics such as construction project management, visualization, cost estimation, clash detection, and sustainable construction. The distribution of newer keywords associated with machine learning, digital twin, computer vision, robotics, artificial intelligence, and smart construction suggests that BIM research extends beyond conventional model-based coordination toward broader digital integration.

These patterns indicate potential directions for further investigation, particularly the integration of BIM with artificial intelligence,

digital twin technologies, and smart construction systems. For developing countries, including Indonesia, future research could examine the technical requirements, organizational readiness, workforce competencies, and interoperability conditions needed to implement these technologies effectively [12], [13]. Nevertheless, the practical priority of each technology should be determined through further assessment of local project needs and implementation constraints.

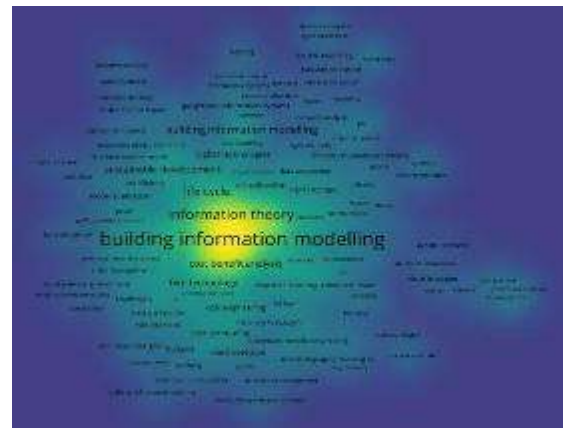


Figure 4. Keyword co-occurrence (density visualization)

Figure 4 presents the density visualization of keyword co-occurrence. In this visualization, colors indicate the relative density of keywords and their surrounding network, with yellow areas representing higher density and green-to-blue areas representing lower density under the selected visualization settings. The denser areas in the map are associated with core BIM-related terms and topics such as information management, cost analysis, visualization, and sustainable development. Other terms, including machine learning, computer vision, digital twin, robotics, and automated compliance checking, appear in areas of comparatively lower density in the displayed map.

The density visualization complements the network and overlay analyses by illustrating the relative concentration of keywords within the research landscape. Taken together, the three visualizations provide complementary perspectives on keyword relationships, the temporal distribution of research topics, and the relative density of terms in the dataset. These results can inform future investigations into BIM implementation, particularly research examining the integration of digital

3.2 Keyword Trends and Thematic Structure

Figure 6. Keyword co-occurrence network (bibliometrix)

Figure 6 illustrates the relationships among keywords in the dataset. The visualization shows a densely connected group of terms, alongside smaller groups associated with topics such as risk, case studies, and visualization. These connections indicate that several BIM research topics are discussed in relation to one another rather than as entirely separate areas of investigation. The network therefore complements the word cloud by showing relationships between terms, rather than only their visual prominence. The interpretation of individual clusters and their colors should be based on the network settings and keyword groupings produced by the analysis.



Figure 5. Keyword word cloud (bibliometrix)

Figure 5 presents the word cloud generated from the bibliographic dataset. The terms “construction industry” and “project management” appear prominently, followed by “lean construction,” “collaboration,” “cost estimation,” “digital twin,” “sustainability,” “scheduling,” and “artificial intelligence” (AI). The prominence of these terms suggests that the analyzed literature addresses BIM not only as a digital modeling technology but also as a tool associated with construction project management, coordination, and process improvement [2], [14]. Other terms, including “blockchain,” “ontology,” “computer vision,” “Internet of Things” (IoT), and “augmented reality,” indicate the presence of research connecting BIM with other digital technologies [5], [9]. However, the word cloud represents the relative prominence of terms in the analyzed dataset and does not, by itself, establish their growth rates over time.

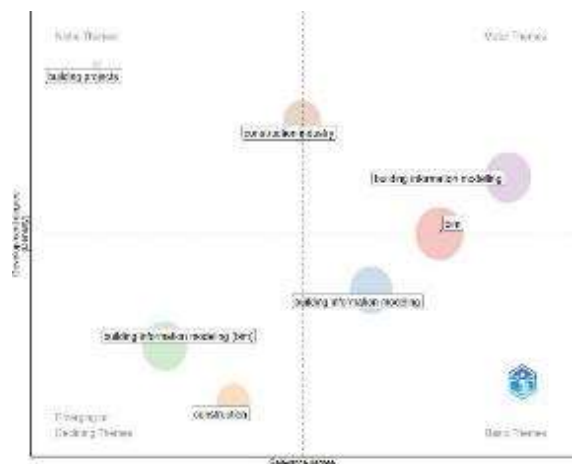


Figure 7. Thematic map of the BIM literature (bibliometrix)

Figure 7 presents the thematic map of BIM-related research based on centrality and density. The map illustrates the relationships and levels of development of the identified themes across four quadrants: motor, niche, basic, and emerging or declining themes.

Overall, the map provides an overview of the thematic structure of BIM research and highlights potential directions for further investigation. The classification of individual themes should be interpreted according to their actual positions in the map.

3.3 Information-Flow Waste in BIM Workflows (VSM)

Value Stream Mapping (VSM) was used as a conceptual framework to examine information flow throughout the BIM workflow, from model authoring and multidisciplinary coordination to approval, construction use, and project handover. The analysis focused on identifying activities that may not add value to the information process, including delays, duplicated work, information inconsistencies, and inefficient data exchange [14], [15]. Based on lean construction principles, eight categories of waste were adapted to the BIM information-flow context, as summarized in (Table 4). The categories illustrate how information-related inefficiencies may occur at different stages of a BIM-enabled construction workflow. For example, modeling errors and inconsistent data may lead to defects and rework, while delayed approvals and fragmented communication may contribute to waiting time. Similarly, repeated file transfers, obsolete model versions, and duplicated data entry may reduce the efficiency of information management. These manifestations are presented as a conceptual synthesis of lean principles and BIM-related workflow issues, rather than as empirically measured occurrences in a specific construction project.

To address these potential inefficiencies, the proposed future-state workflow emphasizes a Common Data Environment (CDE) supported by Open BIM and Industry Foundation Classes (IFC) to facilitate structured information exchange and improve coordination across disciplines. Digital Twin integration is proposed as a further development to connect BIM information with relevant operational or asset data where appropriate [24], [25], [29]. However, the effectiveness of this proposed workflow has not been empirically validated in the present study. Therefore, the framework should be interpreted as a conceptual

improvement approach that requires validation through construction project case studies.

Table 4. Eight Categories of Waste in BIM Information Flow

No	Waste Category	Manifestation in BIM Information Flow
1	Defects	Modeling errors, missing or inconsistent attributes, and clashes identified at later stages.
2	Overproduction	Models developed beyond the level of detail required for the relevant project stage and deliverables that are not used.
3	Waiting	Delays in model approval, responses to requests for information (RFIs), and information exchange between disciplines.
4	Non-utilized talent	BIM personnel primarily assigned to drawing extraction rather than coordination, analysis, or problem-solving activities [13].
5	Transportation	Repeated file transfers and format conversions between software applications or project teams.
6	Inventory	Obsolete model versions and duplicate files stored across multiple platforms or locations.
7	Motion	Time spent searching for information across fragmented folders, platforms, and information systems.
8	Extra processing	Rework, repeated data entry, and duplicated coordination activities.

Source: Authors' synthesis based on lean construction literature

3.4 State of the Art and Research Gaps

Despite the growing body of research on Building Information Modeling (BIM), several research gaps remain. First, BIM studies address diverse topics, including project management, cost estimation, sustainability, safety, and digital technologies. However, these topics are not always examined within an integrated framework that connects BIM implementation with information-flow efficiency and lean construction principles [2], [3], [14].

Second, the integration of systematic literature review (SLR), bibliometric analysis, and Value Stream Mapping (VSM) remains insufficiently explored in the context of BIM-enabled construction workflows. Bibliometric analysis can reveal research patterns and thematic relationships, while VSM can provide a process-oriented perspective for identifying potential information waste. Combining these approaches may therefore offer a more comprehensive understanding of BIM implementation challenges [14], [15].

Third, BIM maturity models and adoption strategies need to account for differences in institutional capacity, workforce skills, technological readiness, and regulatory environments. Models developed in advanced economies may not fully reflect the conditions of developing countries, including Indonesia. Context-specific assessment frameworks are therefore needed to support more appropriate BIM implementation strategies [4], [12].

To address these gaps, this study combines bibliometric analysis, qualitative synthesis, and a conceptual VSM framework to identify potential information waste and propose future research directions. Empirical studies are still needed to validate the framework and its proposed roadmap.

3.5 Research Novelty and Roadmap

This study contributes methodologically by integrating SLR, bibliometric analysis, and VSM; conceptually by examining information waste in BIM workflows through lean principles; and contextually by focusing on developing countries, particularly Indonesia and Southeast Asia [14], [15]. It proposes three

principles: BIM information flows can be analyzed using lean methods; information waste may contribute to project inefficiency; and BIM adoption strategies should reflect local technological, workforce, and regulatory conditions [12].

The study proposes three outputs: a current-state BIM information-flow map, a future-state BIM–Lean workflow supported by CDE and Open BIM/IFC, and a BIM–VSM roadmap for 2026–2030. The roadmap comprises three phases: (1) 2026–2027, developing contextual BIM maturity models and validating the proposed workflow in Indonesian projects [4]; (2) 2028–2029, exploring BIM integration with AI and Digital Twins in infrastructure projects and updating BIM curricula [26], [28]; and (3) 2030, strengthening national BIM standards and CDE adoption in public projects [29]. These proposals require further empirical validation.

CONCLUSION

4.1 Conclusion

This study examined BIM implementation trends, challenges, and future directions by combining SLR, bibliometric analysis using VOSviewer and bibliometrix, and a conceptual VSM approach. Analysis of 647 Scopus records revealed research themes connecting BIM with project management, cost estimation, sustainability, Digital Twins, AI, and lean construction [2], [3], [8], [14], [19], [24]. Key adoption challenges in developing countries include limited skilled personnel, interoperability issues, and regulatory constraints [11], [12].

The conceptual VSM identified eight categories of potential information waste in BIM workflows and proposed CDE and Open BIM/IFC as approaches to improving information exchange [15], [29]. This study contributes an integrated analytical framework and practical recommendations for researchers, practitioners, policymakers, and educators. However, the proposed framework and roadmap require validation through empirical case studies.

4.2 Suggestion

Based on the findings and limitations, the following recommendations are proposed:

1. Future studies should validate the proposed BIM–Lean workflow and 2026–2030 roadmap through Indonesian construction project case studies.

2. Bibliometric research should consider combining Scopus with other databases, such as Web of Science and Dimensions, to broaden literature coverage.

3. Civil engineering curricula should incorporate BIM-related developments, including AI, Digital Twins, and CDE, to strengthen industry-relevant competencies [26], [30].

4. Government agencies and professional associations should strengthen BIM standards and develop implementation policies for public construction projects [29].

5. Construction practitioners should integrate lean principles with BIM and adopt CDE platforms progressively to address information waste [14], [15].

6. Further research should examine BIM implementation in roads, bridges, and dams, particularly in Indonesia and Southeast Asia [28].

7. Context-specific BIM maturity models should be developed to reflect the technological capacity, workforce, and regulatory conditions of developing countries [4].

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