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RESEARCH ARTICLE OPEN ACCESS

A BIBLIOMETRIC REVIEW OF BUILDING INFORMATION MODELING FOR QUANTITY TAKEOFF: TRENDS, THEMATIC CLUSTERS, AND FUTURE DIRECTIONS

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ABSTRACT

Building Information Modeling (BIM) has transformed the construction industry by enhancing visualization, coordination, and decision-making. Despite its growing adoption, limited attention has been given to its application in Quantity Takeoff (QTO), a critical process for cost estimation. This study addresses this gap by conducting a systematic and bibliometric analysis of BIM-QTO research using the Scopus database. Annual publication trends, geographical distribution, and keyword co-occurrence networks were analyzed to identify emerging patterns. VOSviewer was employed to map thematic clusters, while extrapolation from selected studies provided insight into practical applications of BIM for quantity estimation. The results indicate that although BIM research has grown exponentially since 2005, studies specifically integrating BIM and QTO remain scarce and geographically concentrated. Keyword analysis reveals strong interconnections between "BIM," "quantity takeoff," and "cost," confirming the centrality of these topics. The study concludes that further empirical research is needed to compare manual and BIM-based quantity estimation methods for specific building components, particularly in terms of accuracy and efficiency. These findings highlight the importance of expanding BIM-QTO research to support evidence-based adoption in the construction industry.

I. INTRODUCTION

Building Information Modeling (BIM) has revolutionized the construction industry by providing a digital representation of the physical and functional characteristics of facilities. As a critical tool in project management [1], BIM enhances collaboration among stakeholders [2] and offers improved project visualization [3]. One of its key applications lies in Quantity Takeoff (QTO) the process of extracting quantities from digital models to support accurate cost estimation and resource allocation [4], [5].

The advent of BIM technologies has significantly streamlined QTO processes, outperforming traditional manual approaches. Automated quantity extraction from 3D models enables more precise calculations, minimizing human error and reducing time-intensive manual measurements [6], [7], [8]. Studies have shown that BIM-based QTO can improve estimation accuracy, compared to conventional methods that rely heavily on 2D drawings and manual interpretation, which often lead to estimation discrepancies [9], [10], [11], [12], [13]. Such improvements are vital for effective project budgeting and decision-making, making BIM an indispensable asset in modern construction practices.

Traditionally, QTO has been a time-consuming and error-prone task involving the interpretation of 2D construction drawings [14], [15]. BIM transforms this paradigm by enabling direct extraction of quantity data from integrated 3D models [16], [17]. BIM software such as Revit, Navisworks, and CostX can automatically generate QTO reports using embedded geometrical parameters and metadata[18], [19], [20]. Recent research indicates that BIM-QTO integration not only reduces human error but also accelerates the process, becoming

a focal point in the development of modern construction methodologies. Accurate cost estimation, a cornerstone of project success, finds its strongest ally in the synergy between BIM and QTO.

In response to this gap, this study addresses the following research question: How has BIM been applied to improve quantity takeoff processes in construction, and what are the prevailing trends, challenges, and research gaps? The objective of this article is to conduct a Systematic Literature Review (SLR) of BIM-based QTO practices indexed in major databases such as Scopus. The study aims to consolidate scholarly contributions, map keyword and country trends, and identify methodological developments in BIM-QTO research.

This review applies a bibliometric and content analysis approach, focusing on engineering-related publications written in English. By combining quantitative mapping with qualitative insights, the study seeks to inform researchers, practitioners, and software developers of the current state of BIM-QTO research and suggest directions for future work.

The main contribution of this article lies in offering an evidence-based overview of how BIM technologies are reshaping QTO processes. In doing so, it establishes a scholarly reference point for improving cost estimation practices in construction, while also highlighting the limitations and challenges that still constrain broader implementation.

II. MATERIALS AND METHODS

This research employs a Systematic Literature Review (SLR) combined with bibliometric analysis to investigate the development and application of Building Information Modeling (BIM) in the context of Quantity Takeoff (QTO). The methodology is adapted from the systematic review protocols, integrating both quantitative bibliometric techniques and qualitative content synthesis to ensure comprehensive coverage and analytical rigor [21], [22], [23], [24], [25]. The methodological workflow is structured and illustrated in Figure 1. This flowchart visually represents the logical progression of the research process.

II.1 RESEARCH BACKGROUND AND JUSTIFICATION

The integration of BIM and QTO has been increasingly explored in construction research, yet literature reviews on this specific intersection remain limited in scope and depth. Existing studies are often fragmented, lacking a consolidated overview of trends, methods, and knowledge gaps. Therefore, a structured and reproducible review methodology is required to synthesize scholarly developments, establish the state of the art, and identify research opportunities in BIM-QTO.

II.2 DATA SOURCE AND KEYWORD STRATEGY

The Scopus database was selected as the primary source of literature due to its comprehensive indexing of high-quality journals [26], [27], [28], [29], [30]. The data collection process was conducted on March 22, 2025, using carefully constructed keyword queries designed to capture both general BIM literature and specific BIM-QTO publications. Two distinct search queries were used to define the study universe (see Table 1). The general BIM query establishes the broader research context, while the BIM-QTO-specific query defines the focused corpus for detailed content analysis. These results represent the study sample, which is considered representative of current scholarly output on BIM-QTO, as it includes both high-impact and emerging studies filtered by strict inclusion criteria.

This Scopus query seeks English language, Open Access journal articles within the engineering subject area that contain either the phrase "building information modeling" or the acronym "bim" in their title, abstract, or keywords. The key difference from the previous query is the added requirement that articles must also contain the phrases "quantity and takeoff" and "material and takeoff," in addition to "building information modeling" or "bim." This narrows the search focus to articles that specifically discuss BIM within the context of quantity and material estimation.

II.3 DATA EXTRACTION AND PROCESSING

All bibliographic data (title, authors, affiliations, abstract, keywords, publication year, and citation count) were exported in RIS format for compatibility with bibliometric software. Duplicate records and non-relevant entries (e.g., conference proceedings, book chapters) were excluded manually. The final dataset was imported into VOSviewer for processing. Bibliometric analysis was conducted to generate: Co-authorship networks (to examine research collaborations), Keyword co-occurrence maps (to visualize research themes), Temporal publication trends (to track topic evolution), dan Geographical distribution of publications (to identify dominant research regions). These analyses offer insight into the intellectual structure and research frontiers of BIM-QTO.

II.4 CONTENT REVIEW AND QUALITATIVE SYNTHESIS

Beyond quantitative mapping, a qualitative review was carried out on all six BIM-QTO articles retrieved. This synthesis allows for the identification of dominant methodological trends and underexplored areas, thus forming the basis for knowledge gap analysis and hypothesis development.

II.5 STUDY LIMITATIONS

This study is limited to Scopus-indexed journal articles written in English and classified under engineering. Publications outside this scope, including non-English or non-journal sources, may contain relevant insights not captured here. Additionally, the analysis relies on keyword-based search strategies, which may overlook papers with inconsistent terminology. Despite these limitations, the methodology ensures transparency and replicability, providing a reliable foundation for both academic and practical advancements in BIM-QTO research.

Table 1: Keyword Queries Used in the Review.

Source	Query	Results
Scopus	((TITLE-ABS-KEY(building AND information AND modeling) OR TITLE-ABS-KEY(bim)) AND (LIMIT-TO (SRCTYPE,"j")) AND (LIMIT-TO (OA,"all")) AND (LIMIT-TO (SUBJAREA,"ENGI")) AND (LIMIT-TO (LANGUAGE,"English")) AND (LIMIT-TO (DOCTYPE,"ar")))	5097
Scopus	((TITLE-ABS-KEY(building AND information AND modeling) OR TITLE-ABS-KEY(bim) AND TITLE-ABS-KEY(quantity AND takeoff) AND TITLE-ABS-KEY(material AND takeoff)) AND (LIMIT-TO (SRCTYPE,"j")) AND (LIMIT-TO (OA,"all")) AND (LIMIT-TO (SUBJAREA,"ENGI")) AND (LIMIT-TO (LANGUAGE,"English")))	6

Source: Authors, (2025).

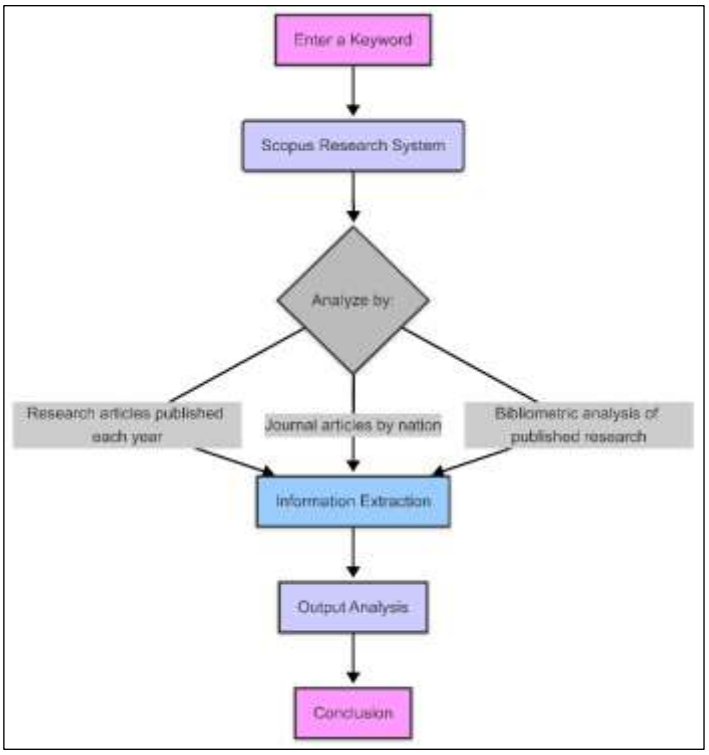

Figure 1: Research Methodology Flowchart.
Source: Authors, (2025).

III. RESULTS AND DISCUSSIONS

The publication trend of Building Information Modeling (BIM) research, as depicted in Figure 3, indicates a significant growth trajectory since its emergence in 2005. A steep increase is evident after 2010, reflecting the rising adoption of digital technologies in the architecture, engineering, and construction (AEC) industry. The exponential model fitted to the data yields a high coefficient of determination ($R^2 = 0.9797$), confirming the robustness of this upward trend, with annual publications surpassing 800 in recent years. This surge highlights not only the academic community's growing interest but also the industry's evolving reliance on BIM as a transformative tool for project planning and execution.

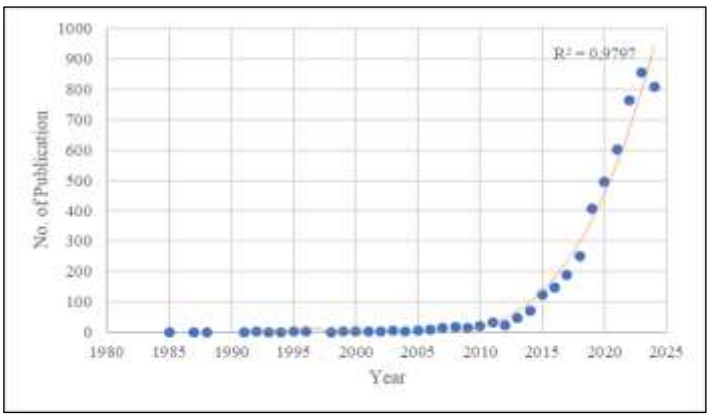

Figure 3: Annual publication trend for Building Information Modeling research.
Source: Authors, (2025).

While the overall BIM research landscape has expanded considerably, a more focused analysis reveals that studies explicitly addressing BIM in conjunction with Quantity Takeoff (QTO) remain limited. As shown in Figure 4, the term “bim-qto” appears only sporadically across the years, with the highest number of publications recorded in 2023 (n = 3). Isolated instances were also observed in 2012, 2020, and 2024, each contributing a single publication. This finding suggests that although the integration of BIM and QTO is an emerging area of interest, it remains underrepresented in the broader body of BIM literature. The relatively recent increase may reflect growing recognition of the need for automated and accurate quantity estimation processes in the construction sector.

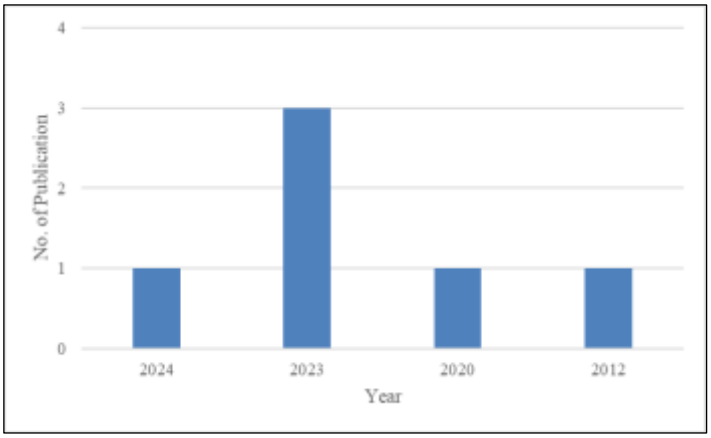

Figure 4: Annual publication trend for BIM-QTO-specific research
Source: Authors, (2025).

In terms of geographic distribution, BIM research is predominantly driven by a few key countries. As illustrated in Figure 5, China leads with 1,004 publications, followed by the United States (n = 570), Australia (n = 305), and other nations such as Canada and the United Kingdom. These figures suggest strong institutional and governmental support for digital innovation in construction within these regions. However, when narrowed down to BIM-QTO-specific publications, the pattern shifts. Figure 6 shows that Vietnam surprisingly leads with two publications, while countries like Canada, China, Japan, Taiwan, Thailand, Turkey, and the United States each contributed one. This distribution indicates that BIM-QTO research is still fragmented and lacks a consolidated academic presence, potentially due to differing priorities, digital capabilities, or data accessibility across regions.

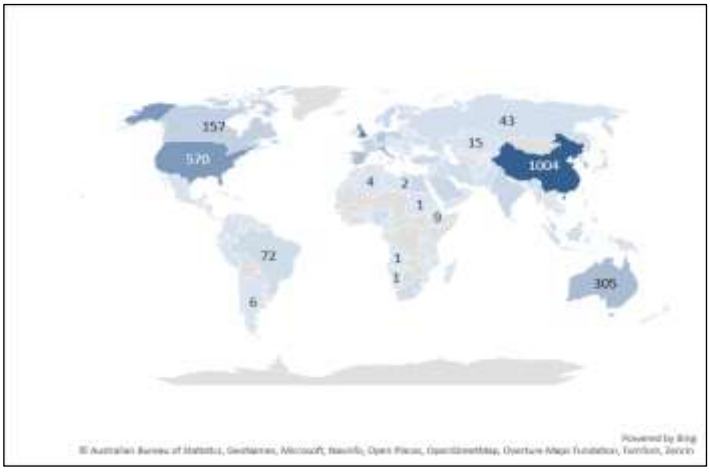

Figure 5: Geographic distribution of BIM research by country
Source: Authors, (2025).

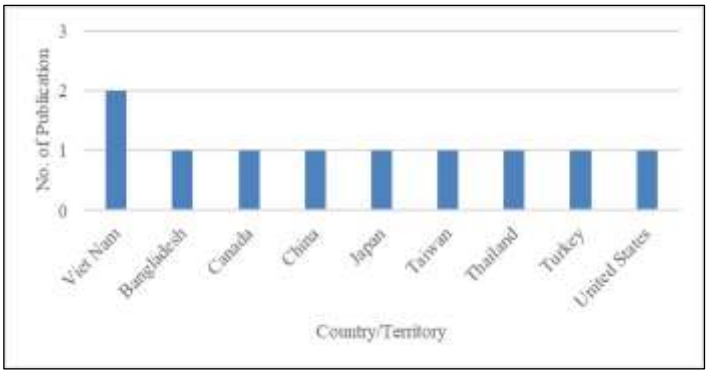

Figure 6: Country-wise distribution of BIM-QTO-specific publications
Source: Authors, (2025).

To further explore the conceptual structure of the research domain, a keyword co-occurrence analysis was performed using VOSviewer based on general BIM-related publications. The visualization shown in Figure 7 reveals three distinct thematic clusters. The red cluster is closely associated with BIM adoption in the construction industry, highlighting terms such as building information modeling, construction management, and cost estimation, which are directly relevant to Quantity Takeoff (QTO) activities. The green cluster emphasizes algorithmic and computational modeling, encompassing keywords such as machine learning, automation, and data integration, which are increasingly being explored to enhance QTO accuracy and efficiency through digital solutions. The blue cluster focuses on sustainability and performance metrics, including life cycle assessment, energy efficiency, and environmental impact, showing that BIM is not only used for design and cost estimation but also for optimizing long-term building performance. The strong linkage between the keywords BIM, quantity takeoff, and cost within these clusters indicates an emerging research focus on integrating digital modeling with cost and quantity analysis. This confirms BIM's growing role as a central platform for automating and improving QTO processes, though the overall volume of dedicated studies in this subdomain remains relatively low.

In contrast, the keyword co-occurrence network for BIM-QTO-specific research, as presented in Figure 8, is notably simpler. Only three dominant terms "bim," "quantity takeoff," and "cost" form the core of this network, with evenly sized nodes and direct interconnections. This indicates a tightly bound thematic scope and reinforces the notion that the literature remains concentrated on foundational aspects of integrating BIM with cost estimation processes. The lack of complexity further implies that advanced topics, such as machine learning integration or real-time QTO, have yet to gain significant traction in this niche domain.

To further enrich the bibliometric findings, this study conducted a thematic review of selected publications from 2012 to 2024 that specifically explored the integration of Building Information Modeling (BIM) with Quantity Takeoff (QTO). As summarized in Table 2, these studies were analyzed based on publication year, detailed research description, and the extracted keywords relevant to BIM-QTO. The results reveal a gradual increase in the quality and focus of research on this subject over time. For instance, studies from 2023 and 2024 provided insights into how BIM facilitates accurate quantity extraction to support sustainability assessment and cash flow planning, marking a notable advancement from earlier, more generalized studies. These works affirm BIM's potential in streamlining QTO processes and enhancing cost-related decisions through automation and integration.

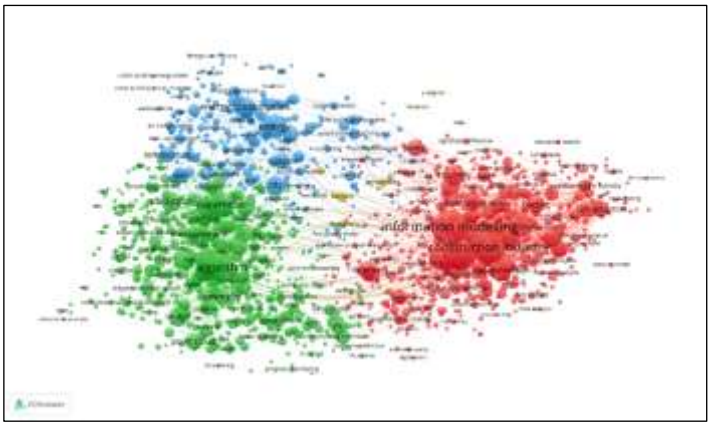

Figure 7: Keyword co-occurrence network in BIM research.
Source: Authors, (2025).

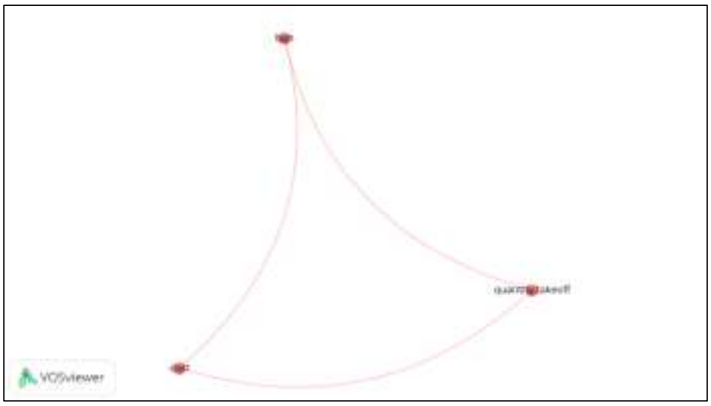

Figure 8: Keyword co-occurrence network in BIM-QTO research.
Source: Authors, (2025).

To further enrich the bibliometric findings, this study conducted a thematic review of selected publications from 2012 to 2024 that specifically explored the integration of Building Information Modeling (BIM) with Quantity Takeoff (QTO). As summarized in Table 2, these studies were analyzed based on publication year, detailed research description, and the extracted keywords relevant to BIM-QTO. The results reveal a gradual increase in the quality and focus of research on this subject over time. For instance, studies from 2023 and 2024 provided insights into how BIM facilitates accurate quantity extraction to support sustainability assessment and cash flow planning, marking a notable advancement from earlier, more generalized studies. These works affirm BIM's potential in streamlining QTO processes and enhancing cost-related decisions through automation and integration.

Specifically, Table 2 shows that the 2024 study emphasized the use of BIM in improving sustainability performance by accurately calculating quantities aligned with environmental, social, and economic indicators. The 2023 studies explored BIM applications in cash flow simulation, project coordination, and cost reduction—all of which rely heavily on precise quantity estimation. Meanwhile, earlier works, such as the 2020 and 2012 publications, highlighted foundational aspects of BIM that laid the groundwork for future integration with QTO, including process efficiency and collaborative modeling. Across these studies, the consistent emergence of "BIM" and "QTO" as primary keywords reflects the growing academic recognition of QTO as a key function within BIM workflows, especially in improving project accuracy, reducing rework, and enhancing decision-making. This trend underscores the need for more empirical studies to deepen our understanding of BIM-QTO synergies and their practical implications in construction management.

Table 2: Summary of Selected BIM-QTO Publications and Generated Keywords.

Year	Detailed Description of the Study	Keywords
2024	This study examines the influence of Building Information Modeling (BIM) adoption on the sustainability performance of construction projects in Indonesia, with a specific focus on how BIM-based quantity takeoff (QTO) contributes to environmental, social, and economic indicators. The quantitative analysis reveals that accurate and efficient QTO using BIM supports improved sustainability outcomes.[31]	BIM, QTO
2023	This case study evaluates the effectiveness of BIM tools in construction project management, emphasizing how QTO functionality within BIM enhances coordination, reduces design errors, and optimizes cost estimation. The analysis also highlights challenges related to system integration and user training.[32]	BIM, QTO
2023	This study explores the integration of Total Quality Management (TQM) with BIM to address project delays and improve cost estimation accuracy. A central theme is the use of BIM for quantity takeoff to support better quality control, error reduction, and cost management in construction projects.[33]	BIM, QTO
2023	This research develops an integrated BIM-based system for cash flow analysis in construction projects. The model links QTO data with cost estimation, scheduling, and financial forecasting, demonstrating improved automation and reliability over manual methods[34]	BIM, QTO
2020	This literature review investigates the synergy between Lean Construction and BIM, particularly in relation to QTO as a tool for minimizing waste and improving material flow efficiency. The study emphasizes BIM-enabled QTO as a driver for Lean implementation.[35]	BIM, QTO
2012	This study explores early applications of BIM in construction with a focus on its capacity to centralize design and quantity data. While the abstract lacks specific detail, it implies that BIM was utilized for QTO to improve collaboration and reduce material estimation errors.[36]	BIM, QTO

Source: Authors, (2025).

Despite these promising applications, a clear research gap persists. Most studies focus on demonstrating the functionality of BIM tools, while few provide systematic comparisons with manual QTO methods. Without such comparative studies, the quantifiable benefits of BIM remain difficult to generalize. Furthermore, most current publications adopt case study approaches with limited sample sizes and contextual diversity, restricting the scope for broader empirical validation.

These limitations underscore the need for future research that employs rigorous methodologies to compare BIM-based and manual approaches in QTO and financial analysis. Empirical data on accuracy would be critical to substantiating the practical advantages of BIM. Moreover, such research could guide best practices and inform policy frameworks for digital adoption in construction. The bibliometric approach employed in this study also offers a replicable framework for mapping other emerging niches within the AEC domain, combining publication analytics with semantic analysis to reveal not only trends but also thematic gaps.

In summary, the results of this study confirm the expanding prominence of BIM in construction research, while simultaneously revealing the infancy and fragmentation of BIM-QTO scholarship. The integration of bibliometric and co-word analysis provides a comprehensive perspective, but the field stands to benefit greatly from targeted empirical studies and broader international collaboration to fully realize the potential of BIM in automated quantity takeoff and cost management.

V. CONCLUSIONS

This study provides a comprehensive bibliometric and thematic analysis of research on Building Information Modeling (BIM), with a specific focus on its integration with Quantity Takeoff (QTO). The results confirm an exponential growth in BIM-related publications, though studies explicitly addressing BIM-QTO remain limited and geographically scattered. Keyword mapping reveals that “BIM,” “quantity takeoff,” and “cost” are strongly interrelated, underscoring their relevance in the construction domain. Thematic extrapolation from selected studies shows increasing attention toward BIM’s role in improving quantity estimation accuracy, particularly in sustainability assessment and financial planning. Despite these advancements, a clear research gap remains in comparative analyses between BIM-based and manual QTO approaches for specific building components.

VI. AUTHOR’S CONTRIBUTION

Conceptualization: Fendi Hary Yanto, Ary Setyawan , Fajar Sri Handayani and Halwan Alfisa Saifullah.
Methodology: : Fendi Hary Yanto andAry Setyawan.
Investigation: Fendi Hary Yanto
Discussion of results: Fendi Hary Yanto, Ary Setyawan
Writing – Original Draft: Fendi Hary Yanto, Ary Setyawan.

Writing – Review and Editing: Fendi and Author Two.
Resources: Fendi Hary Yanto, Ary Setyawan.
Supervision: Ary Setyawan , Fajar Sri Handayani and Halwan Alfisa Saifullah.
Approval of the final text: Fendi Hary Yanto, Ary Setyawan

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