Recent Trends of BIM Research to Enhance Construction Waste Management

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ABSTRACT

In recent times, the rapid growth in construction waste generation has raised significant environmental and economic concerns in recent times. However, Building Information Modelling (BIM) has emerged as a promising solution for managing construction waste and promoting sustainability. BIM offers advanced capabilities for visualization, simulation, and data-driven decision-making, making it a valuable tool for optimizing waste reduction strategies in construction projects. This paper offers a thorough and in-depth review that examines the present and prospective trends of BIM research and its implications in the realm of construction waste management (CWM). Through a Bibliometric analysis, a total of 637 publications were collected from the "Web of Science" core database. Employing VOSviewer for analysis and visualization, co-occurrence, co-word analysis, cluster analysis, and co-citation analyses were conducted to explore influential authors and journals, high-frequency keywords, recent research trends, and potential future research directions in the field. The findings shed light on crucial topics in BIM for CWM, such as circular economy, recycling, waste estimation, and waste reduction. The study systematically analyzes and categorizes the existing literature, mapping the knowledge landscape, and highlights the main future trends in academic research on the integration of BIM and CWM. Looking ahead, future research is anticipated to focus on integrating BIM with Internet of Things (IoT) models, incorporating circular economy BIM systems, exploring green building using BIM models, implementing BIM-based design for deconstruction, and adopting multi-dimensional BIM frameworks. This comprehensive review provides innovative insights into the unique contributions of BIM for CWM, differentiating it from prior research and enhancing the paper's scholarly impact.

Keywords: Building Information Modelling, BIM, Construction Waste Management, CWM, Sustainability, Construction Waste.

INTRODUCTION

Over the past few years, Building Information Modeling (BIM) has transformed the construction industry by enhancing how projects are conceptualized, designed, and executed. Simultaneously, the escalating generation of construction waste has raised critical environmental and economic concerns. The construction industry is a major contributor to waste accumulation, which results in resource depletion, land consumption, and water contamination [1]. In many regions, particularly developing countries, construction waste is still predominantly disposed of in landfills with minimal recycling efforts [2]. Consequently, the need for sustainable and efficient Construction Waste Management (CWM) strategies has become increasingly urgent. Despite increasing global commitments to sustainable construction, the sector continues to face critical challenges in managing waste efficiently. BIM offers theoretical promise, yet its practical implementation in CWM remains uneven and under-analysed across regions and project scales.

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One of the most promising solutions in this domain is BIM-driven CWM, which enables construction professionals to optimize waste reduction, improve material efficiency, and integrate real-time waste monitoring into project workflows. BIM facilitates precise waste estimation, clash detection, and simulation-based design modifications, ensuring that construction processes generate minimal waste. Notably, researchers have demonstrated how BIM can assist in rebar waste reduction through simulation-based design optimizations [6] and in developing waste estimation systems using BIM models [7]. Furthermore, BIM enables the automatic extraction of key data—including object size, volume, and location—improving waste quantification accuracy compared to manual processes [8]. These advancements underscore BIM's growing significance in revolutionizing waste management practices in the construction sector.

RESEARCH METHODOLOGY

A systematic review is a quantitative method for analysing scientific research progress [13]. Utilising bibliometric tools, the review provides an evidence-based analysis intended to inform future research directions and practical implementation [14]. The review employed a systematic approach to gather relevant literature from the Web of Science (WOS) database [10]. The choice of WOS database for this study is grounded in its comprehensive and reliable nature, making it a preferred resource for conducting bibliometric analyses in the field of Building Information Modelling (BIM) and Construction Waste Management (CWM). With access to over 18,000 journals and an extensive collection of cited references, WOS offers a robust platform for tracking the latest scholarly developments [1]. Its reputation for indexing high-quality, peer-reviewed articles ensures that the data used in this review is both credible and representative of current academic trends [11]. In contrast to other databases, such as Scopus, IEEE Xplore, or Google Scholar, WOS stands out for its superior citation metrics, impact factor tracking, and interdisciplinary reach, which are essential for a study that spans multiple domains, including civil engineering, sustainability, and environmental sciences. While Scopus similarly provides broad coverage, WOS is favoured for its more rigorous approach to citation tracking and its refined filtering mechanisms, which ensure the inclusion of high-impact research. IEEE Xplore, though a valuable resource for technological studies, is more focused on engineering disciplines and thus offers a narrower scope for the integrative and interdisciplinary focus required by this research. Moreover, Google Scholar, while expansive, lacks the same level of academic filtering, potentially introducing variability in citation counts and journal rankings, making it less reliable for bibliometric analysis. Therefore, WOS was deemed the most suitable database for this review [10], offering a comprehensive and consistent dataset necessary for a thorough investigation of the evolving role of BIM in CWM.VOSviewer software was selected for bibliometric analysis due to its capacity to manage extensive datasets and generate visual representations of scholarly networks [15]. The analysis comprised four principal components: keyword co-occurrence to identify central research themes; author co-citation to reveal influential scholars; journal co-citation to determine key publication venues; and document co-citation to uncover foundational texts in the field [16]. A total of 637 publications were retrieved using targeted keyword searches [17]. Analysis of subject classifications indicated that 23% of the papers fell under Green Sustainable Science and Technology, 17% under Environmental Engineering, and 16% under Civil Engineering. A geographical analysis revealed that China and Australia are leading contributors, with China producing 229 documents and 3,084 citations, and Australia contributing 96 documents with 1,392 citations [18]. The dominance of China and Australia may reflect governmental emphasis on digital construction and environmental regulation, warranting deeper analysis of national policy influence on academic output. Table 1 outlines the distribution of documents and citations by country.

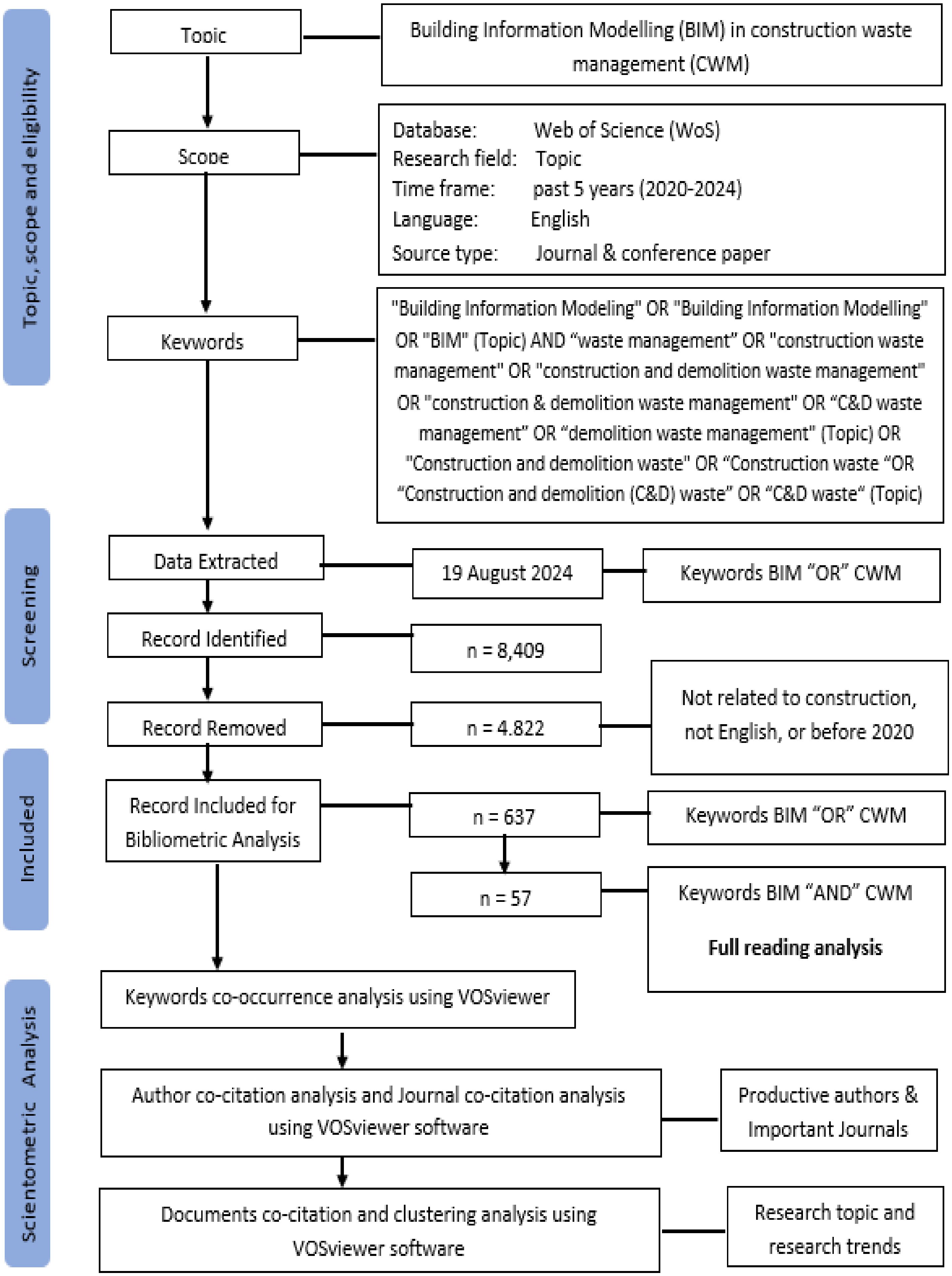

Figure 1. Flow diagram of the PRISMA search methodology.

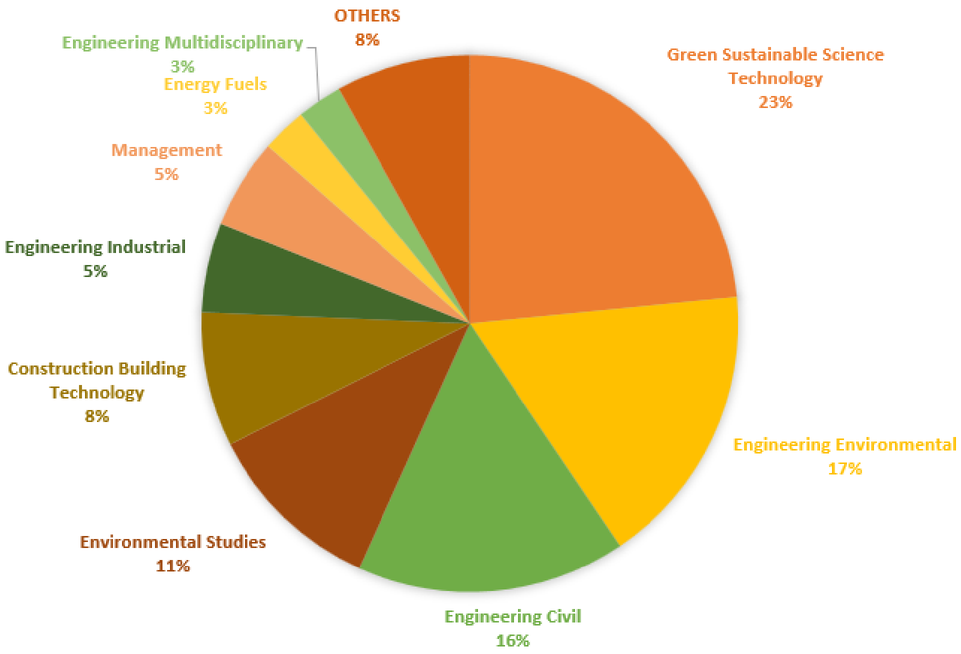

Figure 2. Publications as classified in terms of research area.

Table 1. Top publications and citation per country.

Country	Documents	Citations	Total link Strength
China	229	3084	785
Australia	96	1392	557
England	74	755	295
USA	46	761	262
India	37	277	146
Spain	37	394	177
Italy	29	289	101
Malaysia	29	401	107
Canada	22	299	136
Brazil	21	264	80
Netherlands	20	194	105
Egypt	15	108	51

Keyword co-occurrence analysis

The resulting network visualizes the relationship between keywords, represented as nodes, in a distance-based manner, with closer nodes indicating a stronger relationship between the keywords [19]. From the 1,994 keywords initially identified, 76 met the threshold for detailed analysis [17]. The keywords were grouped into six thematic clusters, with the most prominent themes including circular economy, sustainability, recycling, BIM, and waste management. These clusters reflect a growing academic interest in integrating sustainable practices with digital innovation [17]. A summary of the most frequently occurring keywords is provided in Table 2.

Table 2. Most frequently used keywords.

Keyword	Occurrences	Total Link Strength
circular economy	91	132
construction and demolition waste	59	74
Sustainability	59	89

BIM	37	42
waste management	33	73
construction industry	31	45
Recycling	31	52
building information modeling	30	42
life cycle assessment	30	46
building information modeling (BIM)	27	24
construction waste	26	35
Construction	22	30
sustainable development	21	31
built environment	17	35
sustainable construction	17	22
building information modelling	15	19
building information modelling (BIM)	11	11
construction projects	10	15
construction waste management	10	13
Reuse	10	26

The six distinct clusters identified offer important insights into the key focus areas and their relationships. Firstly, the prominence of the "circular economy" cluster suggests a strong emphasis on exploring circular principles and strategies to address construction and demolition waste. This aligns with the growing global movement towards a more sustainable and resource-efficient built environment. However, the close associations with keywords like "sustainability," "recycling," and "reuse" indicate that researchers are examining the synergies between circular economy approaches and construction waste management.

The "BIM" cluster highlights the increasing role of BIM technology in the context of construction waste management. The links to keywords such as "waste management" and "construction projects" suggest that researchers are investigating how BIM can be leveraged to enhance waste identification, quantification, and optimization throughout the construction lifecycle. This is a promising area of research, as BIM's data-rich modelling and visualization capabilities can potentially enable more informed decision-making and waste reduction strategies. While, the "recycling" and "waste management" clusters further underscore the importance of exploring waste treatment and disposal strategies within the research domain. The emphasis on keywords like "construction and demolition waste" and "reuse" indicates a focus on developing practical solutions for the management and valorisation of construction waste streams. While “circular economy” frequently co-occurs with BIM, few studies operationalise this relationship beyond conceptual alignment, pointing to a disconnect between academic discourse and practical application.

Authors co-citation analysis

By creating network maps, VOSviewer helps to uncover relationships and connections between various elements in the knowledge domain in a systematic manner [21]. The diagram of the author co-citation network, illustrated later in Figure 7, visually represents the interconnections among authors whose works are cited together in the same documents. This network consists of 102 nodes and 3,539 links, encompassing 22,982 authors who meet the minimum citation threshold of 20. To streamline the network and eliminate redundant links, we employed network pruning using the pathfinder function [22]. The size of each node corresponds to the frequency of co-citations received by a specific author, indicating their prominence within the network. The links between nodes signify citation relationships, reflecting the number of citations established between authors. Utilizing VOSviewer in this systematic review shows the co-citation patterns and author relationships within the research field. As per the statistical analysis conducted using VOSviewer, Figure 5 presents the findings regarding the frequency of author publications in BIM for CWM research. Lu WS emerges as the most prominent author with 36 publications, followed closely by Cheng JCP with 31. Tam VWY has contributed 23 publications, while Wang J, Kim S, and Liu Y each have around 21 publications. Other notable contributors include Li H and Marzouk M with 20 publications each, and Chong HY with 19. Several authors, including Chan DWM, Liu Z, Rahman RA, Wang Q, and Zhang JS, each have 18 publications, while Othman rounds out the list with 17. These authors and entities have made significant contributions to the field and their works have garnered substantial attention and recognition. However, the concentration of influential works within a narrow author cohort suggests potential epistemic centralisation, possibly constraining methodological diversity in BIM-CWM research.

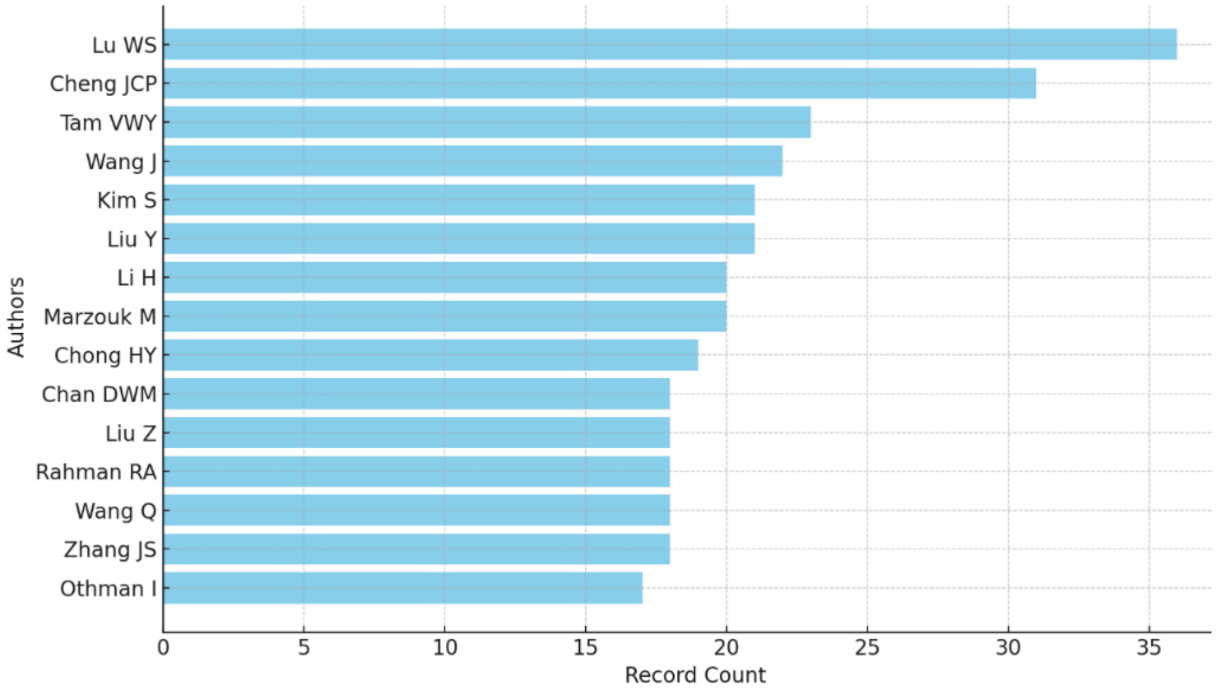

Figure 5. Authors with the strongest citation bursts.

The analysis of journal co-citation

Table 4 provides a comprehensive compilation of the main sources, comprising both journals and conference proceedings, that have made significant contributions to the academic literature in the realm of BIM-CWM. The threshold for selection was set at 5, resulting in a total of 28 source from the initial 190 resource.

Table 4: Most contributed journals in the BIM-CWM research area.

Source	Documents	Citations	Publication %
Sustainability	85	913	13
Journal Of Cleaner Production	65	1548	10
Buildings	47	315	7
Journal Of Building Engineering	19	291	3
Automation In Construction	18	85	3
Engineering Construction and Architectural Management	18	165	3
Environmental Science and Pollution Research	16	125	3
Waste Management	15	261	2
Waste Management & Research	14	109	2
Construction And Building Materials	10	142	2
Journal Of Construction Engineering and Management	10	96	2
Resources Conservation and Recycling	10	359	2
Applied Sciences-Basel	9	55	1
Sustainable Cities and Society	9	37	1
Building And Environment	8	57	1
International Journal of Construction Management	8	70	1

Built Environment Project and Asset Management	7	37	1
International Journal of Environmental Research and Public Health	7	83	1
Recycling	6	48	1
Energy And Buildings	5	54	1
International Journal of Building Pathology and Adaptation	5	20	1
Materials	5	24	1
Renewable & Sustainable Energy Reviews	5	188	1
Smart And Sustainable Built Environment	5	15	1

Table 4 showcases the leading sources of academic publications in the context of BIM research related to CWM, utilizing data collected from the WOS database. The table displays the document and citation counts for each source. Notably, the journal "Sustainability" emerges as the prominent contributor, featuring 85 published documents and an impressive 913 citations. On the other hand, the “Journal of Cleaner Production” follows closely with 65 documents and 1548 citations. Other notable sources include “Buildings” with 47 documents and 315 citations, “Journal of Building Engineering” with 19 documents and 291 citations, and “Automation in Construction” with 18 documents and 85 citations. Additionally, “Engineering Construction and Architectural Management” has 18 documents and 165 citations, while “Environmental Science and Pollution Research” has 16 documents and 125 citations. “Waste Management” and “Waste Management & Research” are also prominent sources with 15 documents and 261 citations, and 14 documents and 109 citations, respectively. Also, Figure 7 illustrates the Journal co-citations network diagram, showcasing the interrelationships and collaborations among different journals.

Documents co-citation analysis

The document co-citation network is a valuable resource for graphically representing and structuring the research field, relying on citation relationships among the selected publications. In this study, we created a document co-citation network comprising 197 nodes and 12,806 links, with a minimum of 15 citations per document. Figure 6 visually presents this network, with each node representing a specific document, and its size reflecting the frequency of co-citations it has received. The connections between nodes illustrate the co-citation relationships among the documents.

VOSviewer utilizes key metrics such as mean silhouette (S) and modularity (Q) to assess the structural properties of the network. These metrics provide insights into the degree of cohesion within clusters and the extent of loose coupling in the co-citation network, signifying the presence of distinct and interconnected groups of related publications within the research field. A value greater than 0.3 suggests that the network exhibits significant clustering [23]. On the other hand, the silhouette score measures the heterogeneity of network clustering. A score greater than 0.5 indicates a heterogeneous clustering pattern within the network. These metrics provide significant insights into the structure and clustering patterns within the document co-citation network. Furthermore, the citation analysis was performed to identify the most highly cited documents among the 637 publications. To ensure precision and relevance, only papers with at least 50 citations were considered. As a result, 25 documents met this threshold, as presented in Figure 7.

Co-authorship Network Analysis

To evaluate the structural properties of the network, VOSviewer utilizes essential metrics, such as the modularity (Q) value, which indicates that the network displays significant clustering [33]. On the other hand, the silhouette score measures the heterogeneity of network clustering. A score greater than 0.5 indicates a heterogeneous clustering pattern within the network. These measurements offer insightful information about the structure and clustering patterns within the document co-citation network.

Figure 8 displays a co-authorship network that highlights the collaborative relationships among researchers who have made significant contributions to the field BIM related to CWM. For inclusion in the network, authors needed to have at least two documents and one citation. Among the 2088 authors in the field, 280 authors fulfilled these criteria and were represented in the network. The network provides insights into the collaborative patterns and connections among these influential authors in the field of BIM related to CWM.

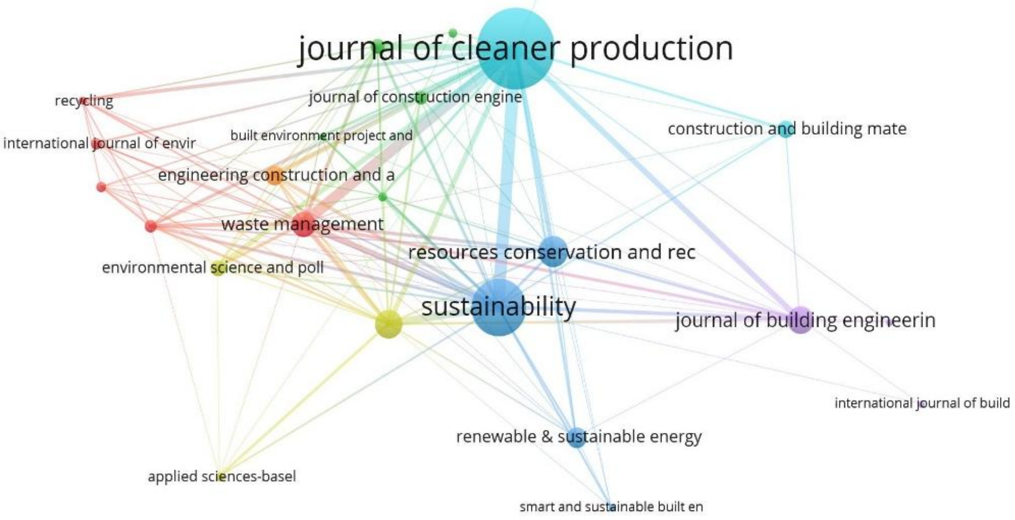

Figure 6. Journal co-citations network.

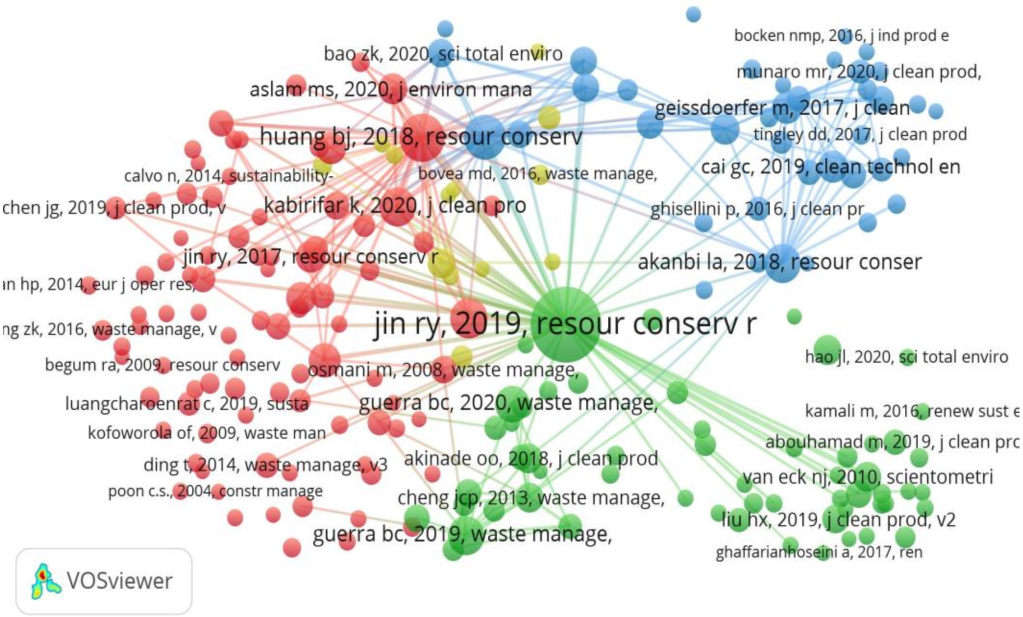

Figure 7. Links visualization of co-citations analysis for the collected data.

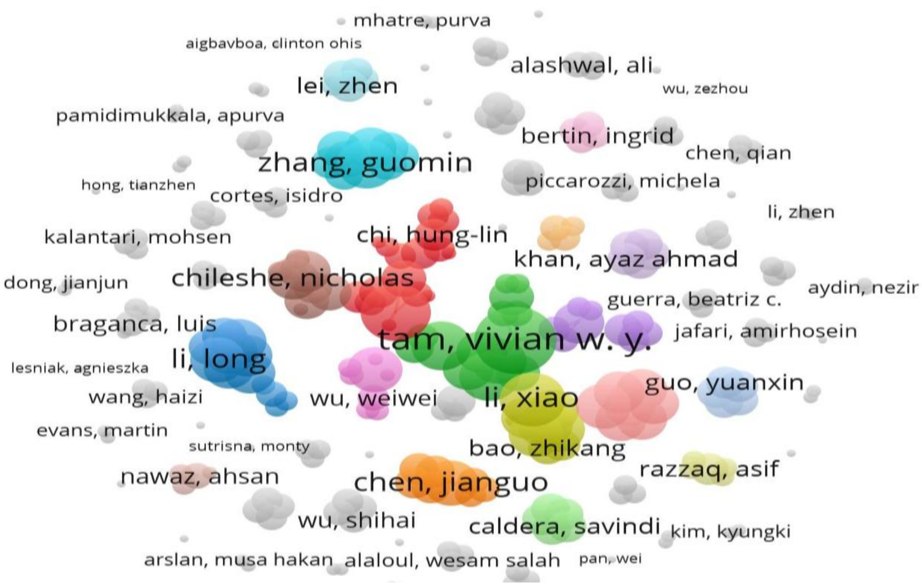

Figure 8. Link visualization among authors.

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DISCUSSION AND FINDINGS

The existing literature reveals a gap in recent knowledge mapping analyses at the intersection of BIM and CWM practices. While substantial research has been conducted on BIM implementation, there remains a lack of comprehensive studies examining its application in CWM across diverse geographic contexts. Addressing this gap necessitates a systematic mapping of the current state of BIM research and its integration into CWM globally. This approach enables an understanding of key trends, emerging challenges, regional disparities, and future research trajectories.

This study analyzed the global distribution of innovation in BIM for CWM research and identified publication trends. A total of 637 relevant documents were extracted from the Web of Science (WOS) database, forming the foundation for a detailed examination of research progress and focus areas. The findings indicate that Asia is at the forefront of BIM-CWM research, followed by Australia, Europe, and North America, while Africa and South America remain underrepresented.

The dominance of Asian countries, particularly China, in BIM-CWM research can be attributed to strong government policies, substantial investments in technological innovations, and an increasing emphasis on sustainable construction practices. In contrast, Africa and South America face significant challenges, including limited access to resources, inadequate infrastructure, and insufficient research funding. Additionally, socio-economic constraints, cultural barriers, and a lack of specialized expertise hinder the adoption and implementation of BIM for CWM in these regions.

A deeper analysis of the publication trends over time suggests a sharp increase in BIM-CWM research output between 2020 and 2022, reaching its peak in 2022. The growing body of literature in this domain aligns with the global shift toward sustainable construction and circular economy principles. However, it is crucial to assess whether this research surge has translated into practical applications and policy implementations.

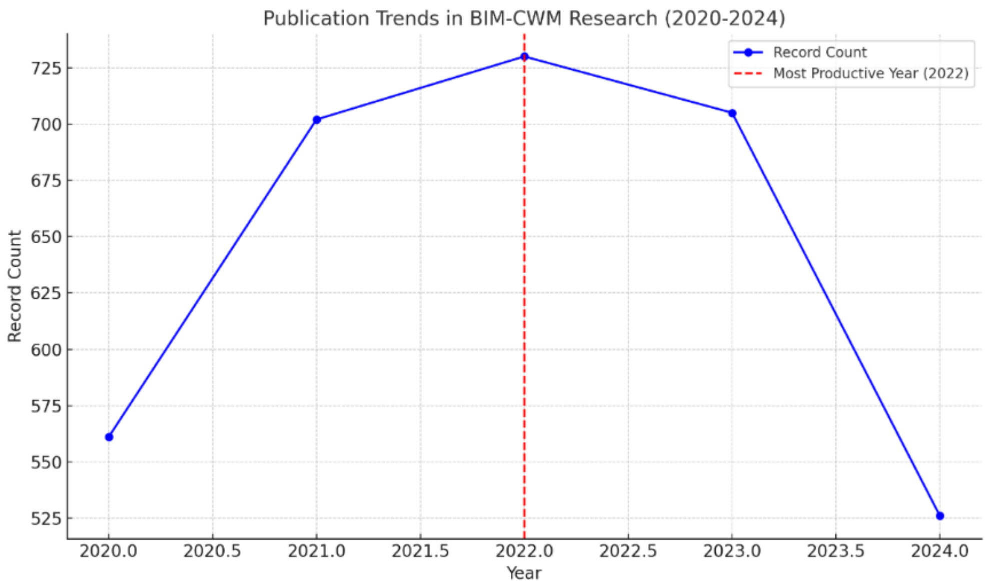

Figure 9. Documents by year of publication.

Analysis of Key Themes and Trends in BIM-CWM Research

1. Keyword Co-occurrence and Research Themes

The keyword co-occurrence analysis identified dominant themes in the BIM-CWM research landscape. These include circular economy, waste estimation, recycling, and sustainable design. In this in-deep analysis, we will delve into the clusters that have been identified and explore the most cited documents within each cluster. By doing so, we aim to gain insights into the key recent research topics and areas of interest. In conclusion, the study has emphasized the significance of analysing the most relevant research papers, categorized by their occurrence frequency in distinct research areas. Through the final screening process, we have successfully identified 57 publications, out of the 637 papers analyzed in this study, all 57 articles included in the analysis were closely aligned with the research topic and underwent thorough and in-depth reading to conduct trend analysis. This rigorous approach has facilitated a thorough exploration and analysis of the current research trends and principal focus areas within the domain of BIM for CWM. Nevertheless, the scarcity of published documents in this domain emphasizes the pressing necessity for further research in this field, as also acknowledged in a previous study by [36].

The field of BIM for CWM exhibits research trends and primary focus areas categorized into three main groups: reviews, practical applications, and innovative models. In the forthcoming section, we will present and examine recent research trends by analysing relevant publications. These trends will be categorized according to the frequency of published documents in each research area. This analysis offers significant insights into the current advancements and focal points within the domain of BIM for CWM. Figure 11. displays the three primary categories and their respective subordinate clusters, providing a visual representation of the relationships and connections within the research trends of the study.

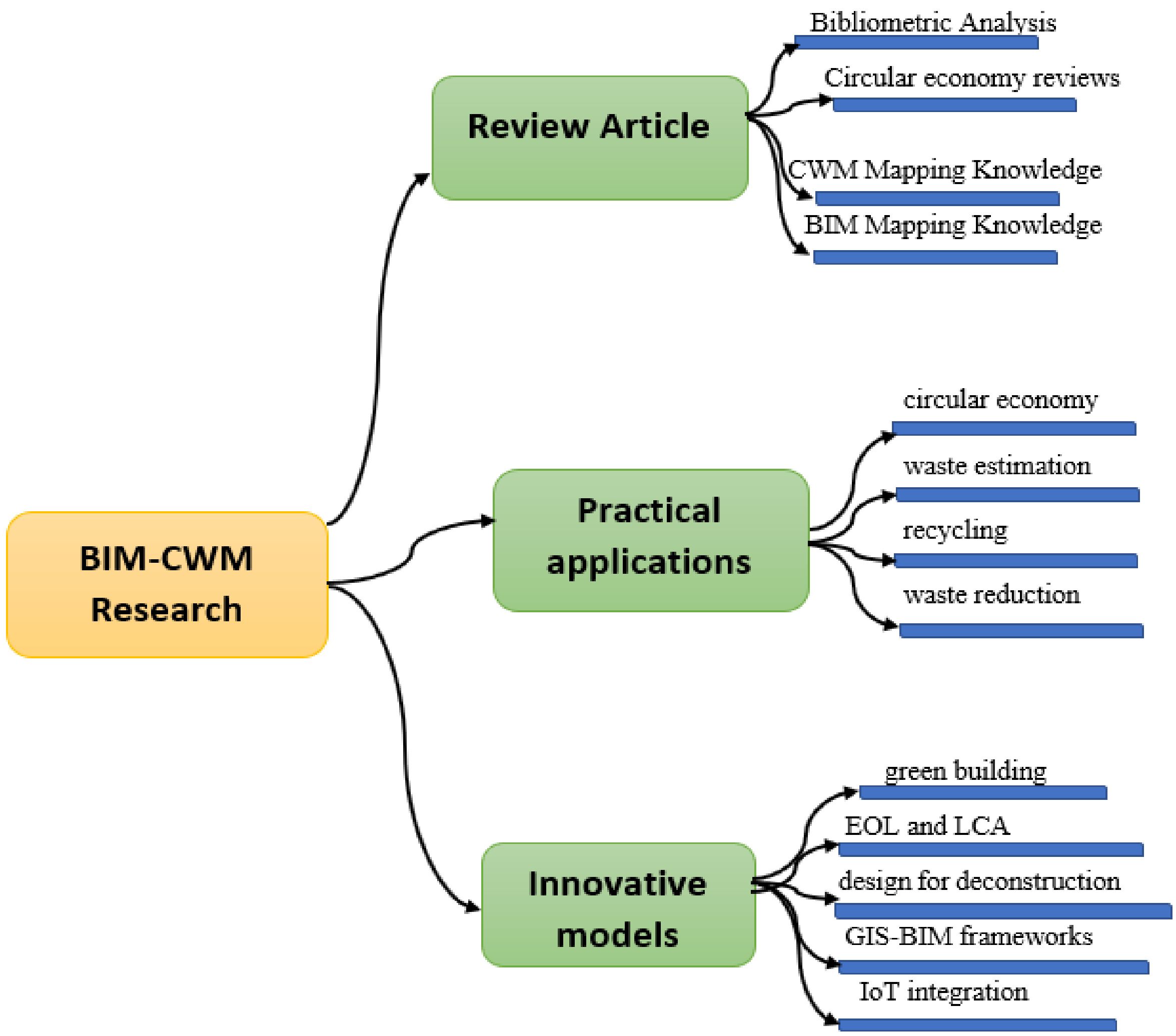

Figure 10. The framework of BIM-CWM research clusters.

The clustering analysis further classified the literature into three main categories:

I) Reviews:

Among the documents selected for analysis, twelve review articles were identified [37–40, 88–91], each offering a unique perspective on the intersection of BIM-CWM. These review articles encompassed diverse themes, such as the scientific mapping of CWM [41, 42, 91], reviewing BIM research for CWM [88] exploration of information technologies related to CWM [38, 42, 43], the examination of BIM-specific challenges in the context of CWM [44, 45], or other related topics [89, 90]. By conducting thorough literature syntheses, these reviews have offered valuable insights into the current state of knowledge, shedding light on essential areas for future research. Moreover, they have deepened our understanding of the interdependent relationship between BIM and CWM. However, the completed reviews have not yet adequately covered crucial practical areas, and they also lack a country-specific focus, which is essential to obtain practical results and assist stakeholders in implementing sustainable solutions, especially in developing countries.

II) Practical Applications:

The literature's third section delves into the practical implementation of BIM in the context of CWM practices and techniques. Utilizing clustering analysis and thorough reading, [92] for example, four primary clusters have been identified in recent research publications:

Circular Economy: Recent research trends emphasize sustainability in developed countries [29, 41, 54–56]. BIM applications facilitate intelligent waste recycling and resource management throughout construction projects [57]. Integrating tools like life cycle assessment (LCA), waste management plans (WMP), and BIM reduces greenhouse gas emissions [37]. Holistic approaches involving all stakeholders throughout the construction lifecycle are crucial for waste reduction and environmental impact minimization [39].

Recycling: Implementing the 3R strategy (reduce, recycle, reuse) in CWM is vital for sustainability. BIM frameworks support efficient waste recovery and recycling during construction [60]. Tools within BIM enable environmental assessments and informed recycling decisions [61, 62]. Sustainable urban mining practices are enhanced through data capture and visualization [63]. These efforts guide eco-conscious CWM, promoting resource efficiency and environmental preservation [64].

BIM-based Waste Estimation: Innovative waste management practices necessitate accurate estimation of construction waste. Studies [60, 65, 66] use BIM to automate waste quantification and integrate it with models like LCA and GIS for better accuracy and decision-making. Precise databases and regional considerations are essential for effective estimation [43].

BIM-based Waste Reduction: BIM aids in waste reduction by enabling methodologies like BIM-LCA for quantitative assessments. Studies [61, 67] demonstrate BIM's role in minimizing waste during design and construction phases. Approaches like automated BIM-based systems [71, 72] and predictive models [73] contribute to sustainable construction practices. However, research gaps in BIM implementation, project management, and cost studies highlight the need for further exploration.

III) Innovative Models:

Among the innovative BIM models aimed at enhancing CWM, scholars have explored various approaches to advance the field. Some researchers, for example, have concentrated on using BIM for fostering green building, as noted in [50, 51]. A key study by Schamne [97] presents a conceptual BIM model using Industry Foundation Classes (IFC) standards, addressing CDW management through improved resource efficiency and environmental analysis. Traditional green building rating systems often use a building-centric evaluation, while BIM has enabled an execution platform [50]. Adopting a user-centric approach, however, allows for a more detailed assessment of sustainability, paving the way for customized evaluation systems. Recent work also highlights the integration of the Internet of Things (IoT) within BIM, enhancing CWM practices [36, 52, 53]. Additional frameworks have been developed, such as the Waste Management Process Flow Model (WMPFM), which utilizes an Android application for CWM [54]. Other studies address the economic potential of construction waste audits [47] and the development of multi-dimensional BIM frameworks for CWM [8]. The incorporation of BIM-based Design for Deconstruction (DfD) as a sustainable strategy has also gained traction, despite [48] indicating higher costs of deconstruction and maintenance over conventional methods. This emphasizes the need for a BIM-integrated, cost-effective approach. Likewise, the assessment of End-of-Life (EOL) and Life-Cycle Assessment (LCA) within BIM frameworks underscores the importance of evaluating environmental impacts across the building lifecycle [49].

2. Influence of Leading Researchers and Journals

The citation analysis revealed that influential scholars such as Lu, Jin, Yuan, Tam, and Ajayi have significantly contributed to advancing knowledge in BIM-CWM. Their research has shaped key debates on the role of BIM in sustainable construction waste management. Leading journals in this field include Sustainability, Journal of Cleaner Production, and Buildings, which provide critical insights into the evolving research landscape.

Implications of Research Trends

1. Circular Economy and BIM for CWM

One of the most significant emerging trends is the integration of BIM into circular economy strategies. Studies have highlighted how BIM can facilitate intelligent waste recycling management, optimize resource utilization, and promote material reuse. However, a critical analysis of these studies reveals a gap in holistic approaches that encompass all stages of construction, from design and procurement to demolition and deconstruction. The existing research primarily focuses on specific components, lacking a comprehensive framework that integrates all stakeholders, including policymakers, contractors, and waste management authorities.

2. BIM for Waste Estimation and Reduction

Accurate waste estimation is crucial for effective CWM, and BIM has emerged as a promising tool in this regard. Several studies have introduced BIM-integrated estimation models, incorporating LCA and GIS to enhance precision. However, a key limitation is the reliance on regional databases for waste quantification indices, which can lead to inaccuracies when applied to different geographical contexts. Future research should focus on developing standardized, globally applicable waste estimation models that account for regional variations in construction practices and material use.

BIM's role in waste reduction is another critical area of research, with studies demonstrating its ability to streamline planning and minimize material waste. Nevertheless, a gap remains in assessing the economic feasibility of these strategies. While BIM-based Design for Deconstruction (DfD) has gained traction, its adoption is hindered by the higher costs associated with deconstruction compared to conventional demolition. There is a pressing need for further research on cost-benefit analyses to support the wider implementation of BIM-driven waste reduction strategies.

3. Integration of IoT and AI in BIM for CWM

Recent studies have explored the integration of IoT and AI with BIM to enhance construction waste management. The potential benefits include real-time tracking of waste generation, predictive analytics for waste minimization, and automated decision-making processes. However, the practical implementation of these technologies remains limited due to technical challenges, high costs, and the lack of industry-wide adoption frameworks. Future research should investigate scalable and cost-effective solutions for integrating IoT and AI into BIM for sustainable CWM.

FUTURE RESEARCH TRENDS ON BIM FOR CWM

After exploring the current key topics in the BIM and CWM field, the subsequent section will investigate future research trends derived from a systematic analysis of the reviewed literature, identification of recurring research gaps, keyword co-occurrence analysis, and thematic clustering. The key research avenues include:

1) Future research should explore the integration of green building systems with BIM models, leveraging BIM's capabilities in sustainable construction [74–77]. This opens up new possibilities to develop innovative frameworks aimed at enhancing CWM practices towards achieving sustainability.

2) Exploring the possibilities of recycling and reducing construction waste to achieve a circular economy, in comprehensive approach, through BIM models opens up numerous promising avenues for future research [78, 79].

3) IoT integrated BIM models for CWM enhancement enhancement [60, 80–82]: The rising enthusiasm for combining IoT solutions with BIM platforms has resulted in a unified perspective of extensive building information merged with real-time sensor data. These distinct capabilities present valuable opportunities for enhancing CWM practices.

4) GIS and BIM integration for CWM [83, 84, 95]: BIM and GIS have become key technologies in construction elements [14]. Their integration offers improved building planning efficiency, rationality, and standardization, providing valuable avenues for enhancing CWM practices.

5) BIM novel system for deconstruction and BIM for Deconstruction (BIMfD) [45, 52, 85, 86]: while BIM can effectively contribute to reducing construction waste through EOL scenario selection, the analysis identifies research gaps in the entire lifecycle of materials, from deconstruction to material/component banks, and back to deconstruction.

6) EOL and LCA BIM integrated frameworks [45, 87]: The BIM-LCA framework shows significant promise in evaluating the environmental consequences of diverse disposal approaches during the EOL phase, presenting valuable practical solutions for CWM.

The analysis presented in this study is the outcome of an exhaustive and comprehensive reading of the carefully curated set of publications closely aligned with the research topic of BIM for CWM. The objective of this analysis is to offer guidance for future investigations in this field.

Potential Research Directions and Methodological Approaches for Advancing BIM-Enabled CWM

The integration of BIM within circular economy frameworks has emerged as a dominant trend, aimed at improving resource efficiency and reducing waste in construction [14]. However, these approaches often fail to consider the full lifecycle of construction processes or involve all relevant stakeholders in the decision-making process [14]. While BIM has shown potential in areas like waste estimation and reduction, there remains a pressing need for standardised frameworks that can be tailored to specific regional contexts and construction practices [16]. Emerging technologies such as IoT and GIS offer promising potential for enhanced waste tracking and planning, yet their implementation is often hindered by high costs, technical challenges, and infrastructure limitations [17]. These challenges suggest that while BIM’s role in CWM is progressing, its practical application in diverse contexts is far from straightforward.

One key area for investigation is the integration of green building systems within BIM models. By leveraging BIM's versatile modelling capabilities, researchers could develop innovative frameworks to seamlessly incorporate sustainable design elements and assess their impact on CWM practices, ultimately contributing to the broader goal of enhancing environmental performance in the construction industry. Furthermore, the possibilities of utilising BIM to enable circular economy approaches in construction warrant scholarly scrutiny. Exploring how BIM can support the recycling and reuse of materials, as well as the establishment of material banks, presents a compelling research agenda with the potential to drive meaningful progress towards waste reduction and material circularity.

The integration of emerging technologies, such as the IoT, with BIM platforms also merits academic inquiry. Investigating how the fusion of real-time sensor data and comprehensive building information can elevate CWM practices could yield valuable insights and practical solutions for the industry. Equally important is the exploration of the synergies between BIM and GIS in the context of CWM. Integrating these complementary technologies offers the promise of enhanced planning, monitoring, and optimisation of construction waste management activities, representing a fertile ground for scholarly exploration. Additionally, the development of BIM-based frameworks for deconstruction planning and material/component bank management holds significant promise. Addressing the research gaps in this area could contribute to a more holistic understanding of the entire lifecycle of construction materials, from deconstruction to reuse and recycling. Finally, the integration of BIM and Life Cycle Assessment (LCA) techniques emerges as a valuable research direction, with the potential to inform decision-making processes around end-of-life scenarios and their environmental implications. Pursuing such an integrated approach could yield practical solutions for sustainable CWM practices.

Collectively, these research avenues underscore the evolving potential of BIM in addressing the pressing challenges of CWM, with the ultimate goal of enhancing sustainability in the built environment. However, despite technical advancements, BIM adoption for CWM is frequently hampered by fragmented stakeholder communication, insufficient training, and resistance to process change at the site level. Future studies should integrate behavioural science to understand resistance to BIM adoption at the organisational level, and collaborate with policy researchers to shape adaptive regulatory frameworks.

CONCLUSIONS

This systematic review provides a thorough analysis of the applications of BIM in construction waste management, categorising the literature into theoretical frameworks, practical applications, and innovative modelling approaches. Despite significant progress in research output, there remains a notable gap in terms of practical adoption and regional adaptation of BIM for CWM. To bridge these gaps, collaborative efforts between academics, practitioners, and policymakers are essential, with a focus on developing flexible, region-specific BIM frameworks that can drive sustainable construction practices and contribute to the global transition towards a circular economy. Several key areas for future research have been identified. These include: the integration of BIM with green building certification systems to promote sustainable construction; the development of regionally adaptable waste estimation models to address specific local challenges; the further incorporation of IoT and GIS into BIM to improve waste tracking and planning capabilities; the development of BIM-based frameworks for deconstruction and material reuse; and the expansion of comprehensive lifecycle and end-of-life assessment frameworks within BIM platforms [14][18]. Future studies should also explore the potential of artificial intelligence (AI) and machine learning (ML) to optimise waste management strategies through BIM, offering the prospect of more dynamic, responsive, and data-driven approaches to CWM.

The study contributes to a deeper theoretical understanding of BIM's evolving role for CWM, highlighting its growing application in enhancing efficiency and sustainability. However, it acknowledges limitations due to reliance on a single database, suggesting that future research should incorporate broader sources. The findings of this study underscore the growing prominence of BIM in the field of CWM. While research output has increased substantially, critical gaps remain in terms of in-depth analyses, practical implementation, and policy integration. Addressing these gaps requires a concerted effort among researchers, industry stakeholders, and policymakers to develop comprehensive, scalable, and regionally adaptable BIM-CWM frameworks. By doing so, the construction industry can achieve more effective and sustainable waste management practices, contributing to global sustainability goals and the circular economy transition. This review highlights the need to reorient BIM-CWM research toward context-specific, stakeholder-inclusive frameworks. Without bridging the policy-practice-research divide, the full potential of BIM in addressing construction waste will remain unrealised.

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

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DECLARATION OF COMPETING INTEREST

The authors declare that the work reported in this study was not affected by any conflicting financial interests or personal connections.

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