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Implementing BIM Technology for Effective Construction and Demolition Waste

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***Abstract*—The construction and demolition (C&D) processes produce a staggering amount of waste. These wastes primarily stem from design inefficiencies, remnants of raw materials, unanticipated alterations in building designs, suboptimal procurement and planning, and inadequate material handling, Addressing these concerns, Building Information Modelling (BIM) emerges as a promising solution to efficiently handle C&D waste by mitigating design issues, alterations, and unnecessary rework. This article delves into exploring the potential of BIM technology in supporting both the building design and construction processes to effectively manage C&D waste. Specifically, it highlights BIM-based strategies aimed at reducing, reusing, recycling, and managing construction waste. These approaches utilize clash detection, quantity take-off, construction activity planning, site utilization planning, and prefabrication to streamline waste management within the construction industry.**

Keywords—Waste Reduction Strategies; Sustainable Construction Practices; Building Information Modelling (BIM); Construction Waste Management

I. Introduction

Construction and demolition waste management is a critical aspect of sustainable development in the construction industry. The effective management of waste generated during construction, renovation, and demolition projects is essential for minimizing environmental impact and promoting resource efficiency. In recent years, Building Information Modeling (BIM) technology has emerged as a promising tool for improving waste management practices in the construction industry [1].

BIM is a digital technology that enables the creation and management of a virtual representation of a building or infrastructure project. It allows for the integration of various data and information throughout the project lifecycle, including design, construction, and operation. BIM has been widely recognized for its potential to enhance waste management practices, from the early design stage to the demolition phase [2].

One of the key advantages of BIM in waste management is its ability to enable accurate estimation of waste generation. By incorporating waste estimation capabilities into the BIM model, construction professionals can better plan and optimize waste management strategies. This includes identifying opportunities for waste reduction, recycling, and reuse of materials [3]. BIM also facilitates the identification of potential clashes or conflicts in the design phase, which can help prevent waste generation during construction [4].

Furthermore, BIM can support the implementation of sustainable practices in waste management. It enables the creation of an economically suitable and environmentally friendly material for constructing green buildings [5]. BIM can also contribute to the circular economy by promoting the deconstruction and recycling of materials from demolished structures [6]. By integrating BIM with other technologies such as Geographic Information Systems (GIS), construction waste can be effectively supervised and controlled [7].

Several studies have highlighted the benefits of BIM in construction and demolition waste management. For example, research has shown that BIM can lead to more efficient waste management and minimization, as well as more accurate estimation of recyclable materials [3]. BIM has also been found to reduce costs and improve scheduling in waste management compared to conventional methods [8]. Additionally, BIM has the potential to support cost-benefit analysis and decision-making in demolition waste management [9].

Despite the potential benefits, the application of BIM in construction and demolition waste management still faces challenges. Factors such as limited software functionality and the need for best practice guidelines have been identified as barriers to the widespread adoption of BIM in waste management [10]. Country-specific contextual factors, including socio-cultural, economic, and regulatory environments, can also impact the promotion and adoption of BIM in construction projects [11].

This paper explores the role of BIM technology in revolutionizing construction and demolition waste management practices. By leveraging BIM's capabilities in clash detection, quantity take-off, construction activity planning, site utilization, and prefabrication, this study aims to investigate how BIM-based strategies can effectively reduce, reuse, recycle, and manage C&D waste, ultimately promoting more sustainable and efficient construction practices.

II. LITERATURE REVIEW

Construction and demolition (C&D) waste management is a critical aspect of sustainable development in the construction industry. The efficient handling and management of C&D waste are essential for minimizing environmental impact and promoting resource efficiency. In recent years, Building Information Modeling (BIM) technology has emerged as a promising solution for improving waste management practices in the construction industry. This section provides a comprehensive review of the literature on construction and demolition waste management using BIM technology, highlighting the key findings and contributions of previous studies.

One study by Jayasinghe et al. [13] conducted a systematic literature review to analyze the application of BIM in reverse logistics supply chain management. The review included 70 articles published between 2006 and 2017 and employed descriptive and thematic analysis. The findings revealed the potential of BIM in improving waste management practices by enhancing the efficiency of material flow and reducing waste generation. The study emphasized the importance of integrating BIM with other technologies and highlighted the need for further research in this area.

Shen et al. [14] focused on mapping approaches for examining waste management on construction sites. The study emphasized the importance of proactive community involvement and consensus building among the public to control waste generation and mitigate environmental impacts. The findings highlighted the potential of BIM in facilitating effective waste management through clash detection, quantity take-off, construction activity planning, site utilization planning, and prefabrication.

Meng et al. [15] conducted a review of integrated applications of BIM and related technologies in the whole building life cycle. The study identified challenges in BIM applications from the perspectives of management, technology, and promotion. The review emphasized the need for comprehensive and systematic approaches to address these challenges and promote the effective use of BIM in waste management practices.

Manowong [16] investigated the factors influencing construction waste management efforts in developing countries, using Thailand as a case study. The study highlighted the importance of economic sustainability and the simultaneous improvement of quality of life and the environment. The findings emphasized the need for effective waste management strategies and the involvement of various stakeholders in developing countries.

Liphadzi et al. [17] conducted a systematic review of the use of BIM tools for effective waste management. The study employed the PRISMA model to evaluate existing studies on BIM for waste management. The findings highlighted the potential of BIM in improving waste estimation, reducing waste generation, and promoting recycling and reuse of materials. The review emphasized the need for further research to address the challenges and barriers to the implementation of BIM in waste management practices.

Several studies have also focused on specific aspects of construction and demolition waste management using BIM technology. For example, Han & Gong [18] conducted a visual analysis of construction waste research based on VOSviewer. The study analyzed the existing international research results and identified the key topics and trends in construction waste management. The findings provided insights into the current state of research and highlighted the areas that require further investigation.

Wang et al. [19] proposed a preliminary study on the integration control platform of construction waste based on "BIM+GIS" technology. The study emphasized the importance of authorized personnel being able to oversee the geographical location of waste sources and disposal sites, review real-time monitoring images of waste disposal sites, and track the traceability information of recycled products. The findings highlighted the potential of BIM and GIS integration in improving waste management practices.

This literature review highlights the potential of BIM technology in construction and demolition waste management. The studies reviewed emphasize the importance of integrating BIM with other technologies, involving various stakeholders, and addressing the challenges and barriers to the implementation of BIM in waste management practices. The findings provide valuable insights into the current state of research and identify areas that require further investigation to optimize waste management practices in the construction industry.

A. Construction and Demolition Waste Management

The planning for managing construction and demolition (C&D) waste encompasses strategies focused on both minimization and proper disposal. C&D waste minimization involves a structured approach termed the 3R principle—reduce, reuse, and recycle. Initiating with reduction forms the primary step to curtail the generation of C&D waste. The subsequent approach involves reusing and recycling generated C&D waste to significantly minimize the amount directed for disposal. Any residual C&D waste that doesn’t fit into the categories of reuse or recycling is directed towards designated disposal facilities for proper management.

Efficient handling of disposal waste requires a systematic approach involving the calculation of the waste quantity, fee assessment, and pre-determining the necessary number of hauling trucks. Accurate estimation and meticulous planning of the 3R strategies and the subsequent disposal of waste form the foundational elements in the planning and execution of waste management initiatives. These activities serve as the backbone for effectively minimizing and vigilantly monitoring C&D waste.

III. BUILDING INFORMATION MODELING

Building Information Modeling (BIM) has gained significant attention in the construction industry due to its potential to improve efficiency, reduce costs, and enhance project outcomes. Several studies have explored the application of BIM in the context of construction and demolition waste management, highlighting its benefits and potential contributions.

Arayıcı et al. [20] conducted a comprehensive evaluation and assessment of BIM technologies for lean architectural practice. The study demonstrated how the adoption and implementation of BIM can lead to efficiency gains and leaner practices in architecture. This highlights the potential of BIM to optimize waste management processes and minimize construction and demolition waste.

Ding et al. [21] focused on the key factors influencing the adoption of BIM by architects in China. The study identified factors such as perceived usefulness, ease of use, and organizational support as critical in the adoption of BIM. This research emphasizes the importance of understanding the factors that drive the adoption of BIM, which can ultimately impact waste management practices.

Liphadzi et al. [22] conducted a systematic review of the use of BIM tools for effective waste management. The study highlighted the potential of BIM in waste management by enabling the prediction of material waste during the early stages of design. This emphasizes the role of BIM in waste reduction and efficient resource utilization.

Sacks et al. [23] explored the interaction between lean construction and BIM in the construction industry. While lean construction and BIM are distinct initiatives, both have significant impacts on the industry. The study highlighted the potential synergies between lean principles and BIM, which can contribute to waste reduction and improved project outcomes.

Hashim et al. [24] investigated the relationship between construction waste causes and BIM-IBS (Industrialized Building System) practices in reducing waste during the project design stage. The study emphasized the importance of integrating BIM and IBS practices to address construction waste issues and promote sustainable waste management.

These studies collectively demonstrate the potential of BIM in construction and demolition waste management. BIM can contribute to waste reduction, efficient resource utilization, and improved project outcomes. By integrating BIM into various stages of the construction process, such as planning, design, and construction, waste can be minimized, and sustainable waste management practices can be implemented.

A comprehensive analysis conducted through a literature review delineated typical applications of Building Information Modeling (BIM) that can be effectively applied across the planning, design, and construction phases. Findings and specifics regarding these identified BIM uses are outlined in Table 1.

TABLE I. APPLICATIONS OF BIM IN THE PLANNING, DESIGN, AND CONSTRUCTION PHASES

BIM		Phase	
use	Plan	Design	Construction
Existing conditions modeling	o	o	o
Quantity take-off (cost estimation)	o	o	o
Phase planning (4D simulation)	o	o	o
Programming	o	o	
Site analysis	o	o	
Design reviews	o	o	
Design authoring		o	
Engineering analysis		o	
Code validation		o	
3D coordination (clash detection)		o	o
Site utilization planning			o
Construction system design			o
Digital fabrication			o
3D control and planning			o

Exploring various BIM applications aimed at mitigating inadequate design, material wastage, and unforeseen alterations in building design while enhancing procurement, site planning, and material handling within construction management, this paper focuses on specific BIM applications: quantity take-off, phase planning (4D simulation), Ensuring Design Integrity: Design Reviews and Clash Detection in BIM, site utilization planning, and digital fabrication. In Figure 1, an illustration depicts the BIM-centric strategies for C&D waste management across the design, construction, and demolition phases.

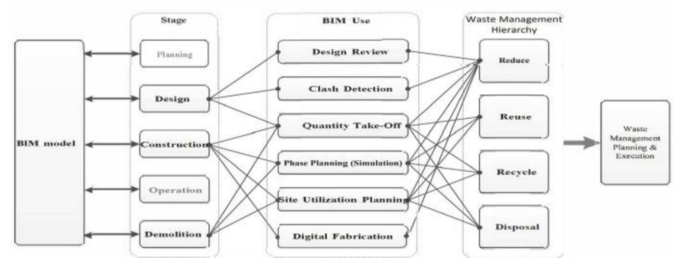

Figure 1. BIM Strategies for Managing Construction and Demolition (C&D) Waste

A. Ensuring Design Integrity: Design Reviews and Clash Detection in BIM

Design integrity plays a crucial role in construction and demolition waste management, as it directly impacts the efficiency and effectiveness of waste reduction strategies. Building Information Modeling (BIM) technology offers valuable tools and processes to ensure design integrity through design reviews and clash detection. This section explores the significance of design reviews and clash detection in BIM for construction and demolition waste management.

Design reviews in BIM involve a comprehensive evaluation of the design model to identify potential issues, conflicts, and inefficiencies. Akponeware & Adamu [25] emphasize the importance of design reviews in identifying coordination problems and quantifying the cost benefits of clash detection. By conducting design reviews, construction professionals can identify clashes and conflicts early in the design phase, allowing for timely resolution and waste reduction.

Clash detection is a critical aspect of design integrity in BIM. It involves the identification and resolution of clashes or conflicts between different building components or systems. Clash detection software in BIM enables the visualization and analysis of clashes, helping to identify potential waste generation points and optimize design coordination. Chahrour et al. [26] highlight the benefits of BIM-enabled clash detection and coordination processes in reducing waste during design.

The effectiveness of clash detection in waste management has been demonstrated in various studies. Chahrour et al. [26] conducted a cost-focused comparative approach to evaluate the benefits of BIM-enabled clash detection and coordination processes. The study highlighted the potential cost savings and waste reduction achieved through the implementation of clash detection during the design phase. Similarly, Primasetra et al. [27] emphasized the importance of clash detection in reducing transportation waste in construction production processes.

To enhance the efficiency of clash detection, researchers have explored methods to filter irrelevant clashes detected by BIM software. Lin & Huang [28] proposed a hybrid method of rule-based reasoning and supervised machine learning to filter out irrelevant clashes. This approach improves the accuracy and effectiveness of clash detection, reducing false positives and optimizing waste management efforts.

Design reviews and clash detection in BIM contribute to effective construction and demolition waste management by identifying and resolving design issues, conflicts, and inefficiencies. These processes enable early intervention and coordination, minimizing waste generation and optimizing resource utilization. By integrating design reviews and clash detection into the BIM workflow, construction professionals can ensure design integrity and promote sustainable waste management practices.

B. Quantity Take-off in BIM for Construction and Demolition Waste Management

Quantity take-off is a crucial process in construction and demolition waste management, as it involves estimating the quantities of materials required for a project. Building Information Modeling (BIM) technology offers significant advantages in streamlining and enhancing the accuracy of quantity take-off processes. This section explores the role of BIM in quantity take-off for effective construction and demolition waste management.

Lu et al. [29] highlight the potential of BIM in computational quantity take-off for waste management. BIM enables designers to compute waste generation instantaneously and present it graphically through a virtual environment. This allows for better visualization and understanding of the quantities of materials involved, facilitating waste reduction strategies.

Ismail et al. [30] conducted a preliminary survey on BIM adoption by quantity surveyors in Malaysia. The study emphasized the significance of BIM in quantity take-off, as it reduces tedious tasks such as measurement and production of Bills of Quantities (BOQ). BIM streamlines the quantity take-off process, improving accuracy and efficiency.

Tanko et al. [31] argued that BIM-based quantity take-off can enhance the procurement process by estimating the materials needed for construction sites, including transportation and labor requirements. By extracting quantity information from BIM models, waste generation can be better predicted and managed.

The benefits of BIM in quantity take-off for waste management have been recognized in various studies. Albtoosh [32] highlighted the role of BIM applications, including quantity take-off, in mitigating cost overruns and change orders in construction projects. BIM enables accurate estimation of material quantities, reducing the likelihood of over-ordering and waste generation.

Researchers have also explored the integration of BIM with other technologies to enhance quantity take-off for waste management. Yin et al. [33] emphasized the use of BIM 3D/4D/5D tools for quantity take-off, enabling the visualization of construction processes and facilitating waste reduction strategies. This integration allows for better planning and optimization of material quantities.

To ensure the effectiveness of BIM-based quantity take-off, guidelines and best practices have been proposed. Yun & Kim [34] emphasized the need for standardized guidelines for quantity take-off in BIM. These guidelines ensure consistency and accuracy in estimating material quantities, supporting waste management efforts.

BIM technology plays a significant role in quantity take-off for construction and demolition waste management. By leveraging BIM's capabilities, such as computational modeling and visualization, quantity take-off processes can be streamlined, leading to more accurate estimations of material quantities. This, in turn, facilitates waste reduction strategies and promotes efficient resource utilization in construction projects.

C. Phase Planning (4D Simulation) in Construction and Demolition Waste Management using BIM Technology

Phase planning, particularly through 4D simulation, plays a crucial role in construction and demolition waste management. Building Information Modeling (BIM) technology offers significant advantages in visualizing and optimizing project schedules, enabling efficient waste management strategies. This section explores the role of 4D simulation in phase planning for effective construction and demolition waste management using BIM.

Pérez & Costa [35] demonstrated the potential of 4D BIM simulation in reducing transportation activities and time, leading to increased production efficiency. By incorporating the time dimension into the BIM model, construction professionals can visualize and analyze the construction sequence, identifying opportunities to optimize transportation activities and minimize waste generation.

Lopez et al. [36] emphasized the usability of 4D BIM in construction and engineering projects. They highlighted the importance of multidisciplinary collaboration and the integration of design and construction teams' inputs into a cloud of data for effective project simulation. This collaborative approach enables better planning and coordination, leading to waste reduction and improved project outcomes.

Vargas et al. [37] emphasized the benefits of using 4D simulation for production planning and control, including analyzing construction site space utilization, resource utilization planning, and improving construction site layout. By simulating the construction process, waste generation can be better predicted and managed.

Wang and Chong Pérez & Costa [38] evaluated the use of 4D models for flow simulation at the operational level, aiming to reduce transportation waste. By simulating the flow of materials and resources, construction professionals can identify bottlenecks and optimize transportation routes, minimizing waste generation.

Jayadi & Riantini [39] developed a standard operating procedure for 4D BIM-based infrastructure construction time planning. This procedure enhanced communication quality and facilitated the simulation and evaluation of construction sequence plans, enabling effective waste management from the perspective of infrastructure contractors.

Nagalli et al. [40] highlighted the potential of 4D modeling for communication on construction sequencing and waste reduction strategies. By visualizing the construction process and simulating different scenarios, construction professionals can identify opportunities to optimize waste management practices.

4D simulation using BIM technology offers significant advantages in phase planning for construction and demolition waste management. By incorporating the time dimension into the BIM model, construction professionals can visualize and optimize project schedules, identify potential waste generation points, and implement effective waste reduction strategies. The integration of 4D simulation into the construction process enhances communication, coordination, and decision-making, leading to improved project outcomes and sustainable waste management practices.

D. *THE WORKFLOW OF BIM-BASED CONSTRUCTION AND DEMOLITION WASTE MANAGEMENT*

As the chosen BIM methodologies for C&D waste management influence design and construction processes, they also impact waste management workflows as shown Figure 2. Mitigating C&D waste during design and construction phases necessitates the elimination of design errors, change orders, and rework through BIM-driven design validation, quantity take-off, and digital fabrication.

Initiating the BIM-supported estimation for C&D waste involves extracting material quantities from a BIM model, integrating them with a construction schedule. Through quantity take-off and a predefined C&D catalog, categorization of C&D waste into inert (e.g., concrete) and non-inert (e.g., wood) waste can be accomplished without additional time or effort. Subsequently, accurate estimation of C&D waste volume, disposal charging fees, and the necessary number of pickup trucks can be facilitated using the waste index. This assists architects and contractors in planning C&D waste management from the project's outset.

Efficient management of C&D waste generated on the construction site is facilitated by site utilization planning. BIM models, integrated with quantities and the project schedule, aid in effectively managing C&D waste on-site.

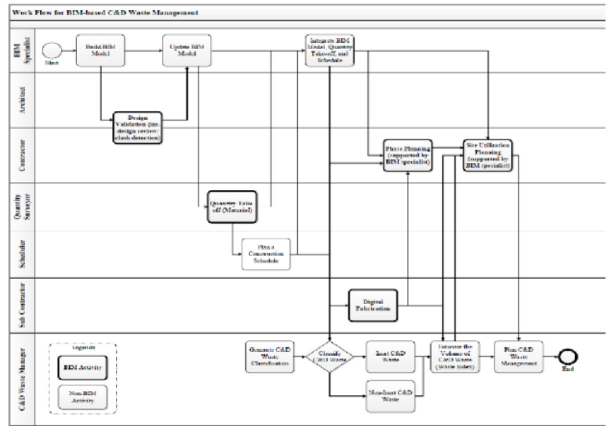

Figure 2. Illustrative Workflow for BIM-Centric Construction and Demolition (C&D) Waste Management

E. Cost Management in Construction and Demolition Waste Management using BIM Technology

Cost management is a critical aspect of construction and demolition waste management, as it directly impacts the financial viability and sustainability of projects. Building Information Modeling (BIM) technology offers significant advantages in cost management, enabling efficient resource allocation and waste reduction strategies.

Kenley [38] emphasizes the importance of learning from case studies in construction cost management. By analyzing real-world projects, construction professionals can identify cost-saving opportunities and best practices. BIM technology provides a platform for capturing and analyzing cost-related data, enabling informed decision-making and cost optimization.

Liphadzi et al. [19] highlight the potential of BIM in reducing the cost of construction and demolition waste management. BIM enables accurate estimation of material quantities, reducing the likelihood of over-ordering and waste generation. By optimizing resource utilization and minimizing waste, construction professionals can achieve cost savings in waste management.

The integration of BIM with other technologies further enhances cost management in construction and demolition waste management. Zou & Feng [39] explore the cost optimization of prefabricated buildings using BIM and finite element simulation. By simulating and analyzing construction processes, construction professionals can identify cost-saving opportunities and optimize waste management strategies.

BIM technology plays a significant role in cost management for construction and demolition waste management. By leveraging BIM's capabilities, construction professionals can accurately estimate costs, optimize resource utilization, and implement cost-effective waste management strategies. The integration of BIM with Lean principles and other technologies further enhances cost management efforts, leading to improved project outcomes and sustainable waste management practices.

IV. Case Study: BIM Technology in C&D Waste Management

Project Overview
Project Name: EcoScape Residences
Location: Sustainable Urban Development, Banten 15315, Indonesia
Construction Period: 24 months
Scope: A mixed-use development focusing on eco-friendly design, comprising residential buildings, commercial spaces, and green areas.

1) Ensuring Design Integrity: Design Reviews and Clash Detection in BIM

Practical Insight: The EcoScape Residences project utilized BIM for design integrity. During the early stages, the architectural and engineering teams collaborated on a centralized BIM platform. Clash detection algorithms identified potential conflicts between structural, mechanical, and plumbing elements. This facilitated early resolution of clashes, preventing on-site issues and subsequent rework. As a result, design changes were made seamlessly within the digital model, preserving design integrity while minimizing material waste and construction delays.

2) Quantity Take-off in BIM for Construction and Demolition Waste Management

Practical Insight: EcoScape Residences implemented BIM for quantity take-off to precisely estimate material requirements. The digital model provided a detailed breakdown of materials needed for each construction phase. By accurately predicting material quantities, the project team could optimize procurement, minimizing over-ordering and reducing excess waste. This approach not only improved waste management practices but also contributed to cost savings.

3) Phase Planning (4D Simulation) in Construction and Demolition Waste Management using BIM Technology

Practical Insight: The project employed BIM's 4D simulation capabilities for phase planning. The construction sequence was visualized in a time-based model, allowing stakeholders to understand the progression of activities. This visualization assisted in planning waste management strategies for each phase, ensuring efficient waste removal and recycling. By aligning waste management plans with construction phases, the project minimized disruptions, reduced on-site congestion, and enhanced overall waste management efficiency.

4) Cost Management in Construction and Demolition Waste Management using BIM Technology

Practical Insight: EcoScape Residences leveraged BIM for comprehensive cost management. The digital model incorporated data on material costs, labor, waste disposal, and recycling expenses. This allowed the project team to conduct accurate cost analyses at different project stages. Cost forecasts and actual expenditures were continuously tracked, enabling proactive decision-making to stay within budget. The integration of cost management within the BIM platform provided a holistic view, aligning financial considerations with waste management strategies.

5) Outcomes:

- 25% reduction in construction and demolition waste compared to industry averages.
- Zero clashes or design-related rework during the construction phase.
- 15% cost savings attributed to optimized waste management and procurement practices.

6) Recommendations for Industry Stakeholders:

a) *Early Adoption of BIM:*

Embrace BIM technology from the project's inception to maximize its benefits throughout the construction and demolition process.

b) *Integrated Training Programs:*

Conduct training programs for design and construction teams to enhance their proficiency in using BIM tools for clash detection, quantity take-off, phase planning, and cost management.

c) *Continuous Improvement:*

Regularly update and refine BIM processes based on project feedback to ensure ongoing efficiency and alignment with waste management goals.

The EcoScape Residences case study validates the claimed benefits of BIM technology in C&D waste management, showcasing its effectiveness in ensuring design integrity, accurate quantity take-off, phase planning through 4D simulation, and comprehensive cost management.
Stakeholders can draw practical insights from this case study to optimize their waste management strategies and enhance overall project efficiency.

V. Conclusion

Construction and demolition waste management is a critical aspect of sustainable development in the construction industry. Building Information Modeling (BIM) technology has emerged as a promising solution for improving waste management practices. This paper has explored the various aspects of construction and demolition waste management using BIM technology, including design integrity, quantity take-off, phase planning (4D simulation), and cost management.

Design integrity is crucial in waste management, and BIM facilitates design reviews and clash detection to identify and resolve issues early in the design phase. This ensures efficient waste reduction strategies and minimizes waste generation. Quantity take-off in BIM enables accurate estimation of material quantities, optimizing resource utilization and reducing waste. The integration of 4D simulation in phase planning allows for better visualization and optimization of project schedules, leading to effective waste management.

Cost management is essential in construction and demolition waste management, and BIM provides tools for accurate cost estimation, resource allocation, and waste reduction strategies. The integration of BIM with Lean principles enhances cost-effective waste management practices. By leveraging BIM's capabilities, construction professionals can control costs, minimize waste generation, and promote sustainable waste management practices.

The literature review has highlighted the potential benefits of BIM in construction and demolition waste management. Studies have demonstrated the effectiveness of BIM in reducing transportation activities, optimizing construction processes, and improving resource utilization. The integration of BIM with other technologies, such as finite element simulation and prefabrication, further enhances waste management efforts.

However, challenges and barriers to the widespread adoption of BIM in waste management still exist. These include limited software functionality, the need for standardized guidelines, and the lack of awareness and knowledge among stakeholders. Further research and development are needed to address these challenges and promote the effective implementation of BIM in construction and demolition waste management.

Overall, the application of BIM in construction and demolition waste management has the potential to significantly improve sustainability and reduce environmental impacts. By utilizing BIM tools and techniques, construction waste can be minimized, leading to more efficient resource utilization and reduced environmental pollution.

In conclusion, the use of BIM technology in construction and demolition waste management has shown promising results and has the potential to revolutionize waste management practices in the construction industry. By integrating BIM into the planning, design, and construction phases, waste can be minimized, leading to more sustainable and environmentally friendly construction practices.

REFERENCES

[1] R. S. Jayasinghe, N. Chileshe, and R. Rameezdeen, “Informationbased quality management in reverse logistics supply chain: A systematic literature review,” *Benchmarking*, vol. 26, no. 7, pp. 2146–2187, Sep. 2019, doi: 10.1108/BIJ-08-20180238/FULL/PDF.

[2] R. Jin, H. Yuan, and Q. Chen, “Science mapping approach to assisting the review of construction and demolition waste management research published between 2009 and 2018,” *Resour Conserv Recycl*, vol. 140, pp. 175–188, Jan. 2019, doi: 10.1016/J.RESCONREC.2018.09.029.

[3] K. Zhang and J. Jia, “Promotion of the Application of BIM in China—A BIM-Based Model for Construction Material Recycling,” *Recycling 2021, Vol. 6, Page 16*, vol. 6, no. 1, p. 16, Mar. 2021, doi: 10.3390/RECYCLING6010016.

[4] M. C. Georgiadou, “An overview of benefits and challenges of building information modelling (BIM) adoption in UK residential projects,” *Construction Innovation*, vol. 19, no. 3, pp. 298–320, Jun. 2019, doi: 10.1108/CI-04-2017-0030/FULL/PDF.

[5] N. M. Liphadzi, I. Musonda, and A. Onososen, “The use of building information modelling tools for effective waste management: A systematic review,” *IOP Conf Ser Earth Environ Sci*, vol. 1101, no. 6, p. 062001, Nov. 2022, doi: 10.1088/17551315/1101/6/062001.

[6] L. B. Jayasinghe and D. Waldmann, “Development of a BIMBased Web Tool as a Material and Component Bank for a Sustainable Construction Industry,” *Sustainability 2020, Vol. 12, Page 1766*, vol. 12, no. 5, p. 1766, Feb. 2020, doi: 10.3390/SU12051766.

[7] A. Wang, N. Wang, K. Li, and F. Ren, “Preliminary study on the integration control platform of construction waste based on ‘BIM+GIS’ technology,” *E3S Web of Conferences*, vol. 237, p. 01034, Feb. 2021, doi: 10.1051/E3SCONF/202123701034.

[8] N. Cahyo Kresnanto, R. I. Ramadhan, M. Willdan, P. Buana, and P. Putra, “BIM’s Contribution as A Sustainable Construction Accelerator,” *Applied Research on Civil Engineering and Environment (ARCEE)*, vol. 4, no. 01, pp. 38–53, Feb. 2023, doi: 10.32722/ARCEE.V4I01.5333.

[9] B. Hamidi, T. Bulbul, A. Pearce, and W. Thabet, “Potential Application of BIM in Cost-Benefit Analysis of Demolition Waste Management,” pp. 279–288, May 2014, doi: 10.1061/9780784413517.029.

[10] M. Bilal *et al.*, “Analysis of critical features and evaluation of BIM software: towards a plug-in for construction waste minimization using big data,” *International Journal of Sustainable Building Technology and Urban Development*, vol. 6, no. 4, pp. 211–228, Oct. 2015, doi: 10.1080/2093761X.2015.1116415.

[11] S. Durdyev, J. Mbachu, D. Thurnell, L. Zhao, and M. Reza Hosseini, “BIM Adoption in the Cambodian Construction Industry: Key Drivers and Barriers,” *ISPRS International Journal of Geo-Information 2021, Vol. 10, Page 215*, vol. 10, no. 4, p. 215, Apr. 2021, doi: 10.3390/IJGI10040215.

[12] L. Y. Shen, V. W. Y. Tam, C. M. Tam, and D. Drew, “Mapping Approach for Examining Waste Management on Construction Sites,” *J Constr Eng Manag*, vol. 130, no. 4, pp. 472–481, Aug. 2004, doi: 10.1061/(ASCE)0733-9364(2004)130:4(472).

[13] Q. Meng *et al.*, “A review of integrated applications of BIM and related technologies in whole building life cycle,” *Engineering, Construction and Architectural Management*, vol. 27, no. 8, pp. 1647–1677, Oct. 2020, doi: 10.1108/ECAM-09-20190511/FULL/PDF.

[14] E. Manowong, “Investigating factors influencing construction waste management efforts in developing countries: an experience from Thailand,” *https://doi.org/10.1177/0734242X10387012*, vol. 30, no. 1, pp. 56–71, May 2017, doi: 10.1177/0734242X10387012.

[15] N. M. Liphadzi, I. Musonda, and A. Onososen, “The use of building information modelling tools for effective waste management: A systematic review,” *IOP Conf Ser Earth Environ Sci*, vol. 1101, no. 6, p. 062001, Nov. 2022, doi: 10.1088/17551315/1101/6/062001.

[16] L. Han and Z. Gong, “Visual Analysis of Construction Waste Research Based on VOSviewer,” *E3S Web of Conferences*, vol. 237, p. 04016, Feb. 2021, doi: 10.1051/E3SCONF/202123704016. [17] Y. Arayici, P. Coates, L. Koskela, M. Kagioglou, C. Usher, and K. O’Reilly, “Technology adoption in the BIM implementation for lean architectural practice,” *Autom Constr*, vol. 20, no. 2, pp. 189– 195, Mar. 2011, doi: 10.1016/J.AUTCON.2010.09.016.

[18] Z. Ding, J. Zuo, J. Wu, and J. Y. Wang, “Key factors for the BIM adoption by architects: A China study,” *Engineering, Construction and Architectural Management*, vol. 22, no. 6, pp. 732–748, Nov. 2015, doi: 10.1108/ECAM-04-2015-0053/FULL/PDF.

[19] N. M. Liphadzi, I. Musonda, and A. Onososen, “The use of building information modelling tools for effective waste management: A systematic review,” *IOP Conf Ser Earth Environ Sci*, vol. 1101, no. 6, p. 062001, Nov. 2022, doi: 10.1088/17551315/1101/6/062001.

[20] R. Sacks, L. Koskela, B. A. Dave, and R. Owen, “Interaction of Lean and Building Information Modeling in Construction,” *J Constr Eng Manag*, vol. 136, no. 9, pp. 968–980, Feb. 2010, doi: 10.1061/(ASCE)CO.1943-7862.0000203.

[21] M. Z. Hashim, I. Othman, N. Abu Bakar, S. H. Hassan, and M. K. Musa, “Relationship of Construction Waste Causes and BIM-IBS Practices in Reducing Waste through Project Design Stage,” *International Journal of Academic Research in Business and Social*

Sciences, vol. 13, no. 2, Feb. 2023, doi: 10.6007/IJARBSS/V13-I2/16361.

[22] A. O. Akponeware and Z. A. Adamu, "Clash Detection or Clash Avoidance? An Investigation into Coordination Problems in 3D BIM," *Buildings 2017, Vol. 7, Page 75*, vol. 7, no. 3, p. 75, Aug. 2017, doi: 10.3390/BUILDINGS7030075.

[23] R. Chahrour *et al.*, "Cost-benefit analysis of BIM-enabled design clash detection and resolution," *Construction Management and Economics*, vol. 39, no. 1, pp. 55–72, 2021, doi: 10.1080/01446193.2020.1802768.

[24] A. Primasetra, D. Larasati, and S. Wonorahardjo, "BIM Utilization in Improving Energy Efficiency Performance on Architectural Design Process: Challenges and Opportunities," *IOP Conf Ser Earth Environ Sci*, vol. 1058, no. 1, p. 012018, Jul. 2022, doi: 10.1088/1755-1315/1058/1/012018.

[25] W. Y. Lin and Y. H. Huang, "Filtering of Irrelevant Clashes Detected by BIM Software Using a Hybrid Method of Rule-Based Reasoning and Supervised Machine Learning," *Applied Sciences 2019, Vol. 9, Page 5324*, vol. 9, no. 24, p. 5324, Dec. 2019, doi: 10.3390/APP9245324.

[26] W. Lu, C. Webster, K. Chen, X. Zhang, and X. Chen, "Computational Building Information Modelling for construction waste management: Moving from rhetoric to reality," *Renewable and Sustainable Energy Reviews*, vol. 68, pp. 587–595, Feb. 2017, doi: 10.1016/J.RSER.2016.10.029.

[27] N. A. A. Ismail, H. Adnan, and N. A. Bakhary, "Building Information Modelling (BIM) Adoption by Quantity Surveyors: A Preliminary Survey from Malaysia," *IOP Conf Ser Earth Environ Sci*, vol. 267, no. 5, p. 052041, May 2019, doi: 10.1088/17551315/267/5/052041.

[28] B. L. Tanko, W. P. Zakka, and W. N. Heng, "BIM in the Malaysian construction industry: a scientometric review and case study," *Engineering, Construction and Architectural Management*, vol. ahead-of-print, no. ahead-of-print, 2022, doi: 10.1108/ECAM-042021-0324/FULL/PDF.

[29] J. A. A. Al-Btoosh, "Building Information Modelling Technology in Mitigating Cost Overruns and change orders in Construction Projects," *Journal of Advanced Sciences and Engineering Technologies*, vol. 4, no. 1, pp. 50–64, Dec. 2021, doi: 10.32441/JASET.04.01.05.

[30] Y. Rui, L. Yaik-Wah, and T. C. Siang, "Construction Project Management Based on Building Information Modeling (BIM)," *Civil Engineering and Architecture*, vol. 9, no. 6, pp. 2055–2061, Oct. 2021, doi: 10.13189/CEA.2021.090633.

[31] S. Yun and S. Kim, "Basic Research on BIM-Based Quantity Take-off Guidelines," *Architectural research*, vol. 15, no. 2, pp. 103–109, Jun. 2013, doi: 10.5659/AIKAR.2013.15.2.103.

[32] C. T. Pérez and D. Bastos Costa, "Increasing production efficiency through the reduction of transportation activities and time using 4D BIM simulations," *Engineering, Construction and Architectural Management*, vol. 28, no. 8, pp. 2222–2247, Oct. 2021, doi: 10.1108/ECAM-02-2020-0132/FULL/PDF.

[33] R. Lopez, H.-Y. Chong, X. Wang, and J. Graham, "Technical Review: Analysis and Appraisal of Four-Dimensional Building Information Modeling Usability in Construction and Engineering Projects," *J Constr Eng Manag*, vol. 142, no. 5, p. 06015005, Dec. 2015, doi: 10.1061/(ASCE)CO.1943-7862.0001094.

[34] F. B. De Vargas, F. S. Bataglin, and C. T. Formoso, "Guidelines to Develop a BIM Model Focused on Construction Planning and Control," *IGLC 2018 - Proceedings of the 26th Annual Conference of the International Group for Lean Construction: Evolving Lean Construction Towards Mature Production Management Across Cultures and Frontiers*, vol. 2, pp. 744–753, 2018, doi: 10.24928/2018/0450.

[35] C. T. Pérez,) ; Costa, and Dayana B, "Evaluation of 4D BIM use to reduce transportation waste in construction production processes," *SIMPÓSIO BRASILEIRO DE GESTÃO E ECONOMIA DA CONSTRUÇÃO*, vol. 11, no. 00, pp. 1–7, Mar. 2021, doi: 10.46421/sibragec.v11i00.35.

[36] A. Jayadi, S. Leni, and S. T. Riantini, "The Development of 4D BIM Based Infrastructure Construction Time Planning Standard Operating Procedure to Enhance Communication Quality from Infrastructure Contractor Perspective," *Journal of International Conference Proceedings*, vol. 2, no. 1, p. 125, Apr. 2019, doi: 10.32535/JICP.V2I1.393.

[37] A. Nagalli, L. O. S. de Oliveira, A. N. Schamne, B. P. Barros, H. D. Hochleitner, and C. J. de Oliveira, "BIM plug-in technology for construction waste quantification," *Revista Brasileira de Gestao Ambiental e Sustentabilidade*, vol. 8, no. 20, pp. 1605–1619, Dec. 2021, doi: 10.21438/RBGAS (2021)082021.

[38] P. R. Kenley, "Construction Cost Management: Learning from Case Studies," *Construction Management and Economics*, vol. 28, no. 5, pp. 545–546, May 2010, doi: 10.1080/01446190903552502.

[39] Y. F. Zou and W. H. Feng, "Cost optimization in the construction of prefabricated buildings by using BIM and finite element simulation," *Soft comput*, vol. 27, no. 14, pp. 10107–10119, Jul. 2023, doi: 10.1007/S00500-023-08239-0

[1] .