Contractor's Controlling Factors Contributing to Effective Construction Waste Management in Building Construction

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Abstract
The rapid expansion of global urbanization has resulted in an exponential increase in the number of construction projects, which in turn has led to a surge in construction waste (CW). Effective construction waste management (CWM) has become an urgent need to mitigate the negative impact of CW on the environment, society, and the economy. All key stakeholders involved in the construction industry, including consultants, designers, contractors, subcontractors, suppliers, and government agencies, are responsible for minimizing CW. Among these stakeholders, contractors play a crucial role in managing material usage at construction sites, and improving their capacity for effective CWM is essential to minimizing CW. In this study, 43 articles were reviewed to identify the factors relevant to contractors contributing to effective CWM in building construction. A total of 53 factors were identified, then analyzed, and synthesized into seven categories: i. Management and leadership (14 factors), ii. Manpower (4 factors), iii. Policy and strategy (7 factors), iv. Materials (7 factors), v. Equipment and tool (5 factors), vi. Construction method and process (10 factors), and vii. Documentation (6 factors). These findings contribute to the existing literature on CWM in building construction by identifying the factors that are critical for contractors to consider in achieving effective CWM. In future research, these factors will be further analyzed and utilized as attributes for developing a maturity model for contractors to assess their CWM in building construction. Such a model will help contractors evaluate their CWM performance and identify areas for improvement, ultimately leading to better CWM practices in the construction industry.

Keywords
Construction Waste Management, Contractors, Sustainable Construction, SDGs

1. Introduction
Construction waste (CW) has drastically expanded over the past few decades, making it a global issue. CW makes up around 30% of all solid waste produced worldwide(Bao *et al.*, 2023) in which the annual generation of solid waste is roughly 2.25 billion tons in 2022 (World-Bank, 2022). CW is a significant economic development issue for most countries. The more CW generated could increases the cost of construction projects, as it requires additional cost for materials, transportation, landfill fees, and labor costs. CW takes up valuable land space that could be used for other economic activities, reducing its overall economic value. Improper disposal of CW can lead to environmental degradation, causing soil, water, and air pollution, which can harm the health of local communities, ultimately resulting in increased healthcare costs, and decreased property values. The construction industry is a significant consumer of natural resources, and inefficient management of these resources can result in depletion, leading to increased costs and decreased economic growth (Bao *et al.*, 2023; World-Bank, 2022).

Effective construction waste management (CWM) is essential for economic development as it can reduce costs, preserve land resources, protect the environment, and ensure the sustainability of the construction industry (Bao *et al.*, 2023). CWM is the application of knowledge, skills, tools, and techniques to construction activities to minimize construction waste (Brioso, 2015; Sasitharan Nagapan *et al.*, 2012). Effective CWM can be achieved by addressing all related factors affecting CWM in management and leadership, manpower, policy and strategy, materials, equipment or tools, construction method and process, and documentation. So, reviewing and identifying as well as integrating all factors affecting the effectiveness of CWM are the objectives of this study.

The global construction sector is expanding due to the potential for construction to boost economic growth and quality of life. The expansion of buildings leads to a sharp rise in CW, which calls for immediate and effective

CWM to minimize waste generation. CW is the byproducts from construction activities, such as concrete, mortar, steel, broken bricks, timber, aluminum, glass, tile, plasterboard, paper, plastics, and other materials (Ganiyu et al., 2020). The efficiency of the construction sector and the environment are both directly impacted by CW generation. Construction projects often experience cost overruns of between 21 and 30% due to material waste (Nilupa et al., 2015). Arguable, the contractors have been viewed as the main party generating massive CW (Janani et al., 2022). According to Nilupa et al. (2015), contractors experience a loss of profit as a result of higher overhead costs and delays, a loss of productivity as a result of more time spent cleaning, and high waste disposal costs as a result of waste generation. It is necessary to understand the importance of CWM to motivate stakeholders, especially contractors, to improve their construction waste management, which would help minimize CW to achieve related goals.

A number of research studies were carried out to identify the factors contributing to the influence of effective CWM and make suggestions for improving those factors to minimize CW (Ganiyu et al., 2020). Identifying and integrating those factors would help to facilitate contractors in determining all causing factors that they would need to improve to get themselves to be more productive with their performance of CWM.

Reduce and Reuse are the two alternatives mainly concerned with the contractor's control in building construction (Kabirifar et al., 2020b; Li et al., 2022; Wu et al., 2017). So, the contractor's controlling factors contributing to effective CWM in building construction are primarily identified based on the alternatives mentioned above.

2. Reviews of previous studies

The construction sector has been identified as a significant contributor to the generation of construction waste (CW). To tackle this issue, several studies have been conducted to explore potential methods for minimizing CW production throughout the various stages of construction, including planning, design, procurement, construction, renovation, and demolition, from various perspectives such as environmental, social, economic, and technical. Newaz et al. (2022) have pinpointed multiple elements that impact CWM streams, which comprise the economic value of diverted materials, onsite sorting potential, knowledge, experience, and training of site operatives, accurate predictions of waste management (WM) costs during tenders, and the identification of improved approaches for CW collection and disposal. Lu et al. (2021) have analyzed the framework of a "zero-waste construction site" by specifying its meaning, system boundary, assessment period, and operation strategies. This investigation demonstrates that achieving the objective of zero-waste is challenging but feasible at individual construction sites. In addition, Lu et al. (2010) have examined the crucial success factors for WM in construction projects, revealing critical success factors, including WM regulations, WM system, awareness of CWM, the utilization of low-waste building technologies, minimized design changes, and staffs training in WM.

Other effective CWM factors for building construction have been reviewed and categorized into the following sections.

2.1. Management and leadership

Effective management and leadership are critical factors contributing to the efficiency of CWM (Begum et al., 2009; Cha et al., 2009). In particular, Saheed O. Ajayi et al. (2017) argue that contractors' management with high waste management (WM) commitments is essential to reducing construction waste. Moreover, Bao et al. (2021) suggest that effective site management can minimize the amount of waste generated during construction. Hence, to enhance CWM, contractors should prioritize improving their management and leadership towards CWM. This can be achieved, for example, by implementing an organization breakdown structure for CWM and ensuring its effective implementation (Cha et al., 2009; Tam, 2008), providing adequate supervision of WM activities with clear instructions (Bakshan et al., 2017; Udawatta et al., 2015), and maintaining precise on-site material control, including inspecting all processes, such as materials upon arrival (Janani et al., 2022; Osmani et al., 2008).

2.2. Manpower

Construction projects rely heavily on human resources, making manpower a crucial factor in ensuring CWM. Cha et al. (2009); Newaz et al. (2022) have identified manpower as one of a key factor contributing to the effectiveness of CWM. To minimize CW at project sites, both studies highlight the importance of providing training and education to staff and workers on CWM management. Umar et al. (2016) similarly noted that inadequate on-site WM can lead to low productivity, which can be attributed to the lack of manpower development. De Magalhães et al. (2017) underscored the significant impact of unskilled labor on material waste and rework. These findings emphasize the critical role of manpower development in CWM, which can help reduce waste and increase productivity in construction projects.

2.3. Policy and strategy

Effective CWM is a crucial for contractors to ensure sustainability and reduce environmental impacts. Number of studies have identified several factors that contribute to the effectiveness of CWM. Among these, a clear policy and strategy are considered essential (Ghaffar et al., 2020; Wang et al., 2014). Bakshan et al. (2017) noted that financial incentives are crucial in promoting waste minimization practices and encouraging construction workers to adhere to WM policies and strategies. Furthermore, Newaz et al. (2022) suggested that contractors should have a formal plan for their WM practices, which includes a WM policy as a necessary component. Such a policy should outline the contractor's commitment to CWM, its objectives, and the strategies intends to implement to achieve effective CWM. This plan can help contractors to monitor and evaluate their CWM practices, identify areas for improvement, and measure their success in achieving their goals.

So, a well-defined policy and strategy, financial incentives, and a formal plan are essential for effective CWM practices.

2.4. Materials

A significant contributor to the effective CWM is material waste. Various studies have highlighted the importance of efficient material delivery and management to reduce CW. For instance, Cha *et al.* (2009); Poon *et al.* (2004); Udawatta *et al.* (2015), emphasized the significance of material use as a key factor in effective CWM. Moreover, Saheed O Ajayi et al. (2017) pointed out that the efficient delivery schedule, usage of the Just in Time delivery (JIT) system, and effective delivery of materials, including efficient job site access, and material protection during loading, transportation, and unloading can help minimize CW.

In addition, Ghaffar et al. (2020) suggested that building materials should retain their value with valuable materials and products, which can also contribute to CW reduction. Similarly, Daoud *et al.* (2021) highlighted that the use of good quality, durable, and standardized materials can help reduce CW.

So, it is suggested that minimizing CW in the building construction requires a combination of factors, including efficient material delivery, use of valuable building materials, and utilization of good quality, durable, and standardized materials. These measures can enhance the effectiveness of CWM and contribute to effective CWM practices (Ajayi *et al.*, 2018; Daoud *et al.*, 2021).

2.5. Equipment and tool

The efficiency and effectiveness of CWM is heavily reliant on the application of appropriate equipment and tools. Previous research studies have consistently identified equipment and tools as key factors contributing to the effectiveness of CWM (Cha et al., 2009; Kabirifar et al., 2020b; Kolaventi et al., 2018). Wu et al. (2017) further emphasized that the availability of sufficient equipment with advanced construction technologies is necessary for construction projects to minimize CW generation.

In order to optimize construction processes and reduce waste, adoption of high technologies is recommended. One such technology is Building Information Modeling (BIM), which has been shown to facilitate construction work and help reduce waste (Ajayi et al., 2015; Bao et al., 2020; Ghaffar et al., 2020). The utilization of BIM in construction projects allows for improved collaboration, enhanced visualization, and better project management. Consequently, BIM can help minimize material waste, reduce project timelines, and enhance project outcomes.

The effective CWM is dependent on the application of appropriate equipment and tools. The adoption of other related advanced construction technologies can further facilitate construction work and help reduce waste. So, it is crucial for contractors to prioritize the availability and utilization of appropriate equipment and technologies to optimize construction processes and minimize waste generation (Kabirifar *et al.*, 2020a; Tam, 2008).

2.6. Construction method and process

Ajayi et al. (2018); Cha et al. (2009); Kolaventi et al. (2020) have all recognized construction methods and processes as primary factors in the generation of CW. In order to minimize CW, it is necessary to provide adequate site space and layout for materials movement, as highlighted by (Bao et al., 2020; Wang et al., 2010; Yuan, 2013b). To further minimize CW, it is recommended that separate bins be set up for waste types and that individual waste be sorted by type from mixed waste at the site with notice categories (Ganiyu *et al.*, 2020; Kolaventi *et al.*, 2020; Newaz *et al.*, 2022). Moreover, bins should be installed on every floor to facilitate waste segregation and disposal, as suggested by (Newaz et al., 2022).

The adoption of prefabricated structural elements and preassembled components such as bathroom and kitchen pods can also help to minimize CW (Daoud et al., 2021; Ghaffar et al., 2020). In addition, maximizing the reuse of construction materials at the site is necessary (Ghaffar *et al.*, 2020). To minimize CW from application processes, (Janani et al., 2022; Osmani et al., 2008; Udawatta et al., 2015) strongly recommend the use of effective and efficient construction techniques.

Finally, it is important to implement an effective waste management (WM) plan to ensure the success of effective CWM. As Lu *et al.* (2021) have highlighted, the effective implementation of a WM plan is crucial for the success of CWM. Overall, these strategies can help to minimize CW during the construction process and promote effective CWM.

2.7. Documentation

Effective document control is a crucial factor for ensuring the smooth running of construction projects, as noted by several studies. Ajayi et al. (2018); Kolaventi et al. (2020) both emphasized the importance of document control in achieving an effective CWM. Similarly, Udawatta et al. (2015); Zhao et al. (2022) argued that proper construction documentation is essential for successful CWM. Minimizing variation orders and design changes during construction is also important for reducing CW, according to (Ajayi et al., 2015; Doust et al., 2020). These authors highlighted the need to consider such factors during the construction process to prevent unnecessary CW generation. Furthermore, obtaining professional quality management and certification (such as ISO, GREEN, etc.) has been found to be a means of reducing CW (Andersson *et al.*, 2022; Ghaffar *et al.*, 2020). Such certifications provide contractors with the necessary procedure to implement effective WM strategies and minimize their environmental impact.

Finally, the importance of maintaining a lesson-learned repository or recording of CWM cannot be overstated (Janani et al., 2022; Li et al., 2022). This documentation is essential for future learning and gradual improvement in CWM practices, enabling contractors to continuously improve their CW strategies and minimize waste generation in the long run.

The details extracted contractor's controlling factors contributing to effective CWM in building construction is shown in Table 1.

Table 1. The extracted contractor's controlling factors contribute to effective CWM in building construction.

No.	Factors/ Attributes	References
I.	***Management and leadership***	
1.	Contractor's awareness of CW impacts on sustainable construction (environmental, economic, and social)	(Fernández-Sánchez *et al.*, 2010; Wang *et al.*, 2014; Zulu *et al.*, 2022)
2.	Contractor's effective and efficient site management (planning, execution, monitoring, and control)	(Bao *et al.*, 2021; Osmani *et al.*, 2008)
3.	Contractors' precise on-site material control (including inspection of all processes, e.g., inspect the materials when they arrive, etc.)	(Janani *et al.*, 2022; Osmani *et al.*, 2008)
4.	Senior management behavior and attitude on CWM	(Begum *et al.*, 2009; Wang *et al.*, 2014)
5.	Contractor's adequate supervision of WM activities with clear instructions	(Bakshan *et al.*, 2017; Udawatta *et al.*, 2015)
6.	Effective coordination and communication among project stakeholders (Contractor vs. designer, consultant, client, subcontractor, supplier, etc.)	(Kabirifar *et al.*, 2020b; Osmani *et al.*, 2008)
7.	Contractor's work experience on CWM and waste minimization culture within the company	(Bakshan *et al.*, 2017; Li *et al.*, 2022)
8.	Contractor's action to reduce CW generation	(De Magalhães *et al.*, 2017)
9.	Contractor's action to reuse CW	(Wu *et al.*, 2017)
10.	Contractor detailed study and well understanding of specifications and drawing and on-time accurate quantification of material/ bill of quantity	(Kabirifar *et al.*, 2020a; Poon *et al.*, 2004)
11.	Organization breakdown structure for CWM	(Cha *et al.*, 2009; Tam, 2008)
12.	Prevent site accidents	(Doust *et al.*, 2020)
13.	Monitor and audit waste management system periodically	(Ghaffar *et al.*, 2020; Tam, 2008)
14.	Looking for and having support from the client (the project owner)	(Kolaventi *et al.*, 2018)
II.	***Manpower***	
15.	Training and education of the engineers and workers on WM and its effectiveness	(Ding *et al.*, 2018; Udawatta *et al.*, 2015)
16.	Workers are assigned solely for waste minimization	(Cha *et al.*, 2009; Kolaventi *et al.*, 2020)
17.	Skilled workers and workmanship	(Kabirifar *et al.*, 2020a)
18.	Engagement of all stakeholders in CWM	(Udawatta *et al.*, 2015)
III.	***Policy and strategy***	
19.	Establish a strict policy on CWM within the company (including the CWM system, criteria for the quality and safety of reusable materials, etc.)	(Andersson *et al.*, 2022; De Magalhães *et al.*, 2017; Ghaffar *et al.*, 2020; Kolaventi *et al.*, 2020; Lu *et al.*, 2010)
20.	REDUCE target for every project and maximize material reduction at the construction site	(Daoud *et al.*, 2021; Ghaffar *et al.*, 2020; Menegaki *et al.*, 2018; Yuan *et al.*, 2022)
21.	REUSE target for every project and maximize material reuse at the construction site	(Saheed O. Ajayi *et al.*, 2017; Menegaki *et al.*, 2018; Wang *et al.*, 2014)
22.	Establish an appropriate waste management plan in an earlier stage of each construction (Including methods to deal with reusable materials)	(Cha *et al.*, 2009; Kolaventi *et al.*, 2020) (Newaz *et al.*, 2022; Poon *et al.*, 2004)

No.	Factors/ Attributes	References
23.	Contractual documents may include WM targets and responsibilities of sub-contractors about decreasing waste and increasing reusable waste (i.e., setting criteria)	(Cha *et al.*, 2009; Ghaffar *et al.*, 2020; Osmani *et al.*, 2008; Zhao *et al.*, 2022)
24.	Financial rewards and incentives for the effectiveness of decreasing and reusing waste	(Jaillon *et al.*, 2009; Kabirifar *et al.*, 2020a; Menegaki *et al.*, 2018)
25.	Contractor's current waste assessments score and future target	(Kolaventi *et al.*, 2020; Li *et al.*, 2022)
IV.	***Materials***	
26.	Having central areas for cutting and storage	(Poon *et al.*, 2004; Tam, 2008)
27.	Adequate protection of material transportation and handling (loading and unloading)	(Saheed O Ajayi *et al.*, 2017; Daoud *et al.*, 2021; Osmani *et al.*, 2008)
28.	Adequate protection of different categories of materials during storage and stacking	(Kabirifar *et al.*, 2020b; Poon *et al.*, 2004; Tam, 2008)
29.	Preventing ordering errors and ordering appropriate material sizes and quantities to avoid excess	(Doust *et al.*, 2020; Janani *et al.*, 2022; Osmani *et al.*, 2008)
30.	Use of quality and durable, and standardized materials	(Ajayi *et al.*, 2018; Daoud *et al.*, 2021)
31.	Adopt Just in Time delivery (JIT) system	(Daoud *et al.*, 2021)
32.	Strong security at the project site (i.e., prevent the loss of materials)	(Fernández-Sánchez *et al.*, 2010)
V.	***Equipment/ tool***	
33.	Use and familiar with the application of BIM	(Ajayi *et al.*, 2015; Ganiyu *et al.*, 2020)
34.	Use and familiar with other related information technologies	(Kabirifar *et al.*, 2020a; Tam, 2008)
35.	Availability and quality of Equipment (tools, machines, and vehicles)	(Wang *et al.*, 2010; Wu *et al.*, 2017)
36.	Use and familiar with the Equipment	(Jaillon *et al.*, 2009; Poon *et al.*, 2004)
37.	Use metal scaffolding and formwork (e.g., rent them from professional suppliers)	(Ding *et al.*, 2018; Tam, 2008; Wang *et al.*, 2014)
VI.	***Construction method and process***	
38.	Adequate site space and the site layout are cleared for materials movement	(Bao *et al.*, 2020; Wang *et al.*, 2010; Yuan, 2013b)
39.	Set up separated bins by waste type and sort out individual waste by type from mixed waste at the site with notice categories	(Cha *et al.*, 2009; Kolaventi *et al.*, 2020; Newaz *et al.*, 2022; Wang *et al.*, 2010)
40.	Efficient use of materials and minimizing the uneconomical cutting shapes and length (including rebar schedule and materials lists to be reused)	(Doust *et al.*, 2020; Osmani *et al.*, 2008; Yuan, 2013a)
41.	Effective implementation of a waste management plan	(Lu *et al.*, 2021; Newaz *et al.*, 2022)
42.	Store waste in easily accessible areas	(Yuan, 2013a)
43.	Bins are installed on every floor	(Newaz *et al.*, 2022)
44.	Adopt prefabricated structural elements	(Daoud *et al.*, 2021)
45.	Adopt preassembled components such as bathroom & kitchen pods	(Daoud *et al.*, 2021)
46.	Minimize waste from application processes (i.e., overpreparation of mortar)	(Janani *et al.*, 2022; Osmani *et al.*, 2008; Udawatta *et al.*, 2015)
47.	Minimize rework at the construction site	(Ding *et al.*, 2018; Yuan *et al.*, 2022)
VII.	***Documentation***	
48.	Variation orders minimization	(Daoud *et al.*, 2021)
49.	Document control of CWM with effectiveness (amounts, kinds, etc.)	(Zhao *et al.*, 2022)
50.	Design changes during construction minimization	(Ajayi *et al.*, 2015; Doust *et al.*, 2020)
51.	Shop drawing detailing errors preventing	(Ajayi *et al.*, 2018; Doust *et al.*, 2020)
52.	Professional quality management and certification (e.g., ISO, GREEN, etc.)	(Andersson *et al.*, 2022; Ghaffar *et al.*, 2020)
53.	Lesson learned repository on CWM	(Janani *et al.*, 2022; Li *et al.*, 2022)

3. Methodology

A literature review is a strategy for gathering and synthesizing prior works that are more or less systematic. An in-depth understanding of a particular research subject is facilitated by a literature review, which also lays a strong foundation for the creation of theory and knowledge (Zhao et al., 2022).

A systematic review of prior publications that are pertinent to CWM is conducted in this work. In order to address specific research problems, a systematic literature review method was used to summarize all related study findings that matched the pre-defined inclusion criteria (Zhao et al., 2022). To find relevant papers, the Scopus search engine was mainly used. Scopus was chosen because it performs the search accurately (Darko et al., 2017) and includes more journal articles than other databases like Web of Science (Chadegani et al., 2013). In addition, Scopus is frequently utilized in review journal articles for construction management (Jin et al., 2019). Only journal papers were chosen for this study's analysis. This is because most systematic literature studies solely utilize journal papers, which are known to be the most relevant and reliable research outputs (Zhao et al., 2022).

The terms "factor," "construction," "building," "waste," and "management" were used in the literature search on Scopus. A list of 63 journal articles was generated from the initial search. The screening process involved a rigorous examination of the titles, abstracts, and keywords. Finally, factor extraction was performed using 43 sorted journal articles. The earliest one was published in 1996 by (Bossink et al., 1996), while the most recent one was published in 2023 by (Bao et al., 2023).

All factors used for the "frequency analysis" came from a thorough literature review. The literature review methodology is shown in Figure 1.

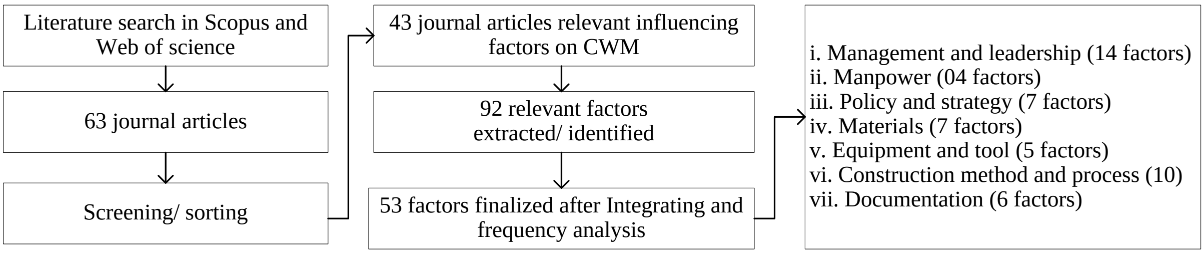

Fig. 1. Literature review methodology

4. Findings and discussions

The aim of this study was to identify the factors that contribute to effective CWM in building construction, with the objective of minimizing the generation of waste through prevention and reuse. The total of 43 articles were reviewed and extracted 92 potential factors that were subsequently analyzed using frequency analysis to identify the most common factors. Factors with a frequency of at least 86% were considered acceptable(Soewin et al., 2022), while factors with a frequency of less than 14% were removed, except for two factors that were retained with a frequency of 13.3%. The remaining 53 factors were classified into seven categories: management and leadership, manpower, policy and strategy, materials, equipment and tool, construction method and process, and documentation. Table 2 bellow presents a comprehensive overview of analysis of the various factors that contribute to effective CWM.

Management and leadership is the most extensively studied category, with the highest number of studies (33) conducted on contractor's awareness of CWM impacts on sustainable construction. The studies highlight the importance of the contractor's effective and efficient site management, precise on-site material control, and senior management's behavior and attitude on CWM. Additionally, contractors' adequate supervision of WM activities with clear instructions, effective coordination and communication among project stakeholders, work experience on CWM, and waste minimization culture within the company are also critical for effective CWM.

In the manpower category, training and education of the engineers and workers on WM and its effectiveness were the most studied factor (33 studies), followed by assigning workers solely for waste minimization (17 studies). Skilled workers and workmanship and engagement of all stakeholders in CWM were also identified as important factors.

Policy and strategy category emphasizes the importance of establishing a strict policy on CWM within the company, setting REDUCE and REUSE targets for every project, and establishing an appropriate WM plan in the early stages of each construction project. The studies also suggest that contractual documents may include WM targets and responsibilities of sub-contractors about decreasing waste and increasing reusable waste, financial rewards and incentives for the effectiveness of decreasing and reusing waste, and contractors' current waste assessment ability and future targets.

In the materials category, having central areas for cutting and storage, adequate protection of material transportation and handling, and adequate protection of different categories of materials during storage and stacking are critical factors in effective CWM. The studies also emphasize preventing ordering errors, ordering appropriate material sizes and quantities to avoid excess, and using quality, durable, and standardized materials.

In the equipment/tool category, it is suggested the importance of using and being familiar with the application of BIM and other related information technologies. Additionally, the availability and quality of equipment, use and familiarity with the equipment, and the use of metal scaffolding and formwork are also important for effective CWM.

In the construction method and process category, it is highlighted the importance of adequate site space and the site layout being cleared for materials movement, setting up separated bins by waste type and sorting out individual waste by type from mixed waste at the site with notice categories, and efficient use of materials and minimizing the uneconomical cutting shapes and length. Effective implementation of a WM plan, storing waste in easily accessible areas, and adopting prefabricated structural elements and preassembled components such as bathroom and kitchen pods are also important.

Lastly, it is suggested that minimizing variation orders, controlling CWM documentation with effectiveness, minimizing design changes during construction, preventing shop drawing detailing errors, and maintaining a lesson learned repository on CWM are critical in the documentation category. Professional quality management and certification, such as ISO and GREEN, are also important.

Therefore, the results showed a comprehensive overview of the various factors that contribute to effective CWM in building construction. It highlighted the importance of management and leadership, manpower, policy and strategy, materials, equipment/tool, construction method and process, and documentation in effective CWM. The findings of this study can be used by contractors to improve their CWM in building construction.

Table 2 is depicted the details results by frequency analysis.

5. Conclusion

The purpose of this study was to identify the factors that contribute to effective CWM in building construction. The total number of 43 articles were reviewed and extracted 92 potential factors, which were subsequently analyzed using frequency analysis. Factors with a frequency of at least 86% were considered acceptable, and those with less than 14% were removed, except for two factors that were retained with a frequency of 13.3%. The remaining 53 factors were classified into seven categories: management and leadership, manpower, policy and strategy, materials, equipment/tool, construction method and process, and documentation.

It is found that effective management and leadership is critical in effective CWM, with the highest number of studies conducted on contractor's awareness of CWM impacts on sustainable construction. Additionally, the study identified training and education of the engineers and workers, assigning workers solely for waste minimization, and engagement of all stakeholders as important factors in the manpower category. The importance of establishing a strict policy on CWM, setting REDUCE and REUSE targets for every project, and establishing an appropriate WM plan in the early stages of each construction project were identified as important factors in the policy and strategy category.

In the materials category, adequate protection of material transportation and handling, and adequate protection of different categories of materials during storage and stacking were critical factors. In the equipment or tool category, it is suggested that the use and familiarity with the application of BIM and other related information technologies, and the availability and quality of equipment are important for effective CWM. The construction method and process category highlighted the importance of adequate site space, separated bins by waste type, and efficient use of materials.

Lastly, in the documentation category, it is suggested that minimizing variation orders, controlling CWM documentation with effectiveness, and maintaining a lesson learned repository on CWM are critical.

These findings can be used by contractors to improve their CWM in building construction.

6. Limitations and future study

The present study focuses on identifying the contractor's controlling factors that contribute to the effective implementation of CWM in building construction. However, it is important to note that this study does not encompass the influencing factors that are associated with the stages of design, procurement, renovation, and demolition. Subsequent to the findings of this study, further research is being conducted to explore the aforementioned influencing factors in greater detail. The contractor's controlling factors identified in this study will be used as attributes to develop a maturity model for contractors to assess their implementation of CWM in building construction.

Table 2. The contractor's controlling factors contribute to effective CWM in building construction.

No.	Categories	Factors/ Attributes	1 (Ganiyu et al., 2020)	2 (Poon et al., 2004)	3 (Lu et al., 2010)	4 (Kabirifar et al., 2020)	5 (Tam, 2008)	6 (Ghaffar et al., 2020)	7 (Kabirifar et al., 2020a)	8 (Daoud et al., 2021)	9 (Wu et al., 2017)	10 (Osmani et al., 2008)	11 (Ajayi et al., 2015)	12 (Li et al., 2022)	13 (Janani et al., 2022)	14 (Jaillon et al., 2009)	15 (de Magalhães et al., 2017)	16 (Bossink et al., 1996)	17 (Ajayi et al., 2018)	18 (Fernández S. et al., 2010)	19 (Andersson et al., 2022)	20 (Ding et al., 2018)	21 (Udawatta et al., 2015)	22 (H. Yuan, 2013)	23 (Saheed O Ajayi et al., 2017	24 (Lu et al., 2021)	25 (Cha et al., 2009)	26 (Kolaventi et al., 2018)	27 (Newaz et al., 2022)	28 (Bao et al., 2020b)	29 (Wang et al., 2010)	30 (Yeheyis et al., 2012)	31 (Bakshan et al., 2017)	32 (Wang et al., 2014)	33 (Begum et al., 2009)	34 (Bao et al., 2021)	35 (Zhao et al., 2022)	36 (Doust et al., 2020)	37 (Menegaki et al., 2018)	38 Kolaventi et al. (2020)	39 (Umar et al., 2016)	40 (Yuan et al., 2022)	41 (Yuan, 2013)	42 (Ajayi et al., 2017)	43 (Zulu et al., 2022)	Number of studies	Number of studies in (%)
1	Management and leadership	Contractor's awareness of CW impacts on sustainable construction (environmental, economic, and social)	√	√	√	√	√	√	√	√	√		√	√			√		√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√		√		√	√					√	**33**	**73.3**
2		Contractor's effective and efficient site management (planning, execution, monitoring, and control)	√		√	√	√	√	√		√	√	√	√	√	√	√	√	√	√	√		√			√		√	√	√	√		√	√		√			√			√	√			**29**	**64.4**
3		Contractors' precise on-site material control (including inspection of all processes, e.g., inspect the materials when they arrive, etc.)	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√		√		√	√			√		√	√	√	√	√	√		√			√					√			**29**	**64.4**
4		Senior management behavior and attitude on CWM	√	√	√	√	√		√	√	√		√	√	√	√	√		√	√	√	√	√						√	√	√		√	√	√	√	√		√							**27**	**60.0**
5		Contractor's adequate supervision of WM activities with clear instructions	√		√	√	√				√	√	√	√	√	√	√	√	√	√		√	√			√			√	√	√		√	√		√			√				√			**25**	**55.6**
6		Effective coordination and communication among project stakeholders (Contractor vs. designer, consultant, client, subcontractor, supplier, etc.)	√	√	√	√		√	√	√	√	√	√			√	√		√		√		√			√	√			√	√		√		√				√				√			**23**	**51.1**
7		Contractor's work experience on CWM and waste minimization culture within the company	√	√		√				√	√	√	√	√	√	√	√	√		√		√	√	√						√			√	√	√											**20**	**44.4**
8		Contractor's action to reduce CW generation		√		√	√		√	√	√		√	√	√	√	√			√	√	√	√										√	√	√		√									**19**	**42.2**
9		Contractor's action to reuse CW		√		√	√		√	√	√		√	√	√	√	√			√	√	√	√										√	√	√		√									**19**	**42.2**
10		Contractor detailed study and well understanding of specifications and drawing and on-time accurate quantification of material/ bill of quantity	√	√	√	√			√	√		√	√		√		√	√	√							√			√	√							√	√								**17**	**37.8**
11		Organization breakdown structure for CWM	√				√		√			√		√	√				√	√	√						√	√	√	√																**13**	**28.9**
12		Prevent site accidents	√		√		√	√				√						√		√			√	√														√								**10**	**22.2**
13		Monitor and audit waste management system periodically					√	√	√		√	√								√	√					√										√										**10**	**22.2**
14		Looking for and having support from the client (the project owner)	√								√					√			√								√	√									√									**7**	**15.6**
15	Manpower	Training and education of the engineers and workers on WM and its effectiveness	√	√	√	√	√	√	√	√	√	√	√	√	√			√		√	√	√	√	√			√	√	√	√			√	√	√		√		√	√	√	√	√		√	**33**	**73.3**
16		Workers are assigned solely for waste minimization							√		√		√	√	√	√						√		√		√	√	√			√		√		√		√			√	√					**17**	**37.8**
17		Skilled workers and workmanship		√				√	√		√			√	√	√	√	√			√	√		√		√							√					√			√					**16**	**35.6**
18		Engagement of all stakeholders in CWM	√	√	√		√	√	√	√			√	√							√	√	√								√		√		√		√									**16**	**35.6**
19	Policy and strategy	Establish a strict policy on CWM within the company (including the CWM system, criteria for the quality and safety of reusable materials, etc.)	√		√	√	√	√		√	√	√	√	√	√	√	√		√		√	√	√		√	√	√	√	√			√	√	√		√	√		√	√	√	√	√	√	√	**34**	**75.6**
20		REDUCE target for every project and maximize material reduction at the construction site	√	√	√	√	√	√		√	√	√	√	√	√	√	√		√			√		√	√	√	√	√				√		√	√		√		√			√		√	√	**29**	**64.4**
21		REUSE target for every project and maximize material reuse at the construction site	√	√	√	√	√	√		√	√	√	√	√	√	√	√		√			√		√	√	√		√				√		√	√		√		√					√	√	**27**	**60.0**
22		Establish an appropriate waste management plan in an earlier stage of each construction (Including methods to deal with reusable materials)		√	√	√		√	√		√	√	√	√	√		√	√	√			√				√	√		√			√	√			√		√	√	√	√	√			√	**26**	**57.8**
23		Contractual documents may include WM targets and responsibilities of sub-contractors about decreasing waste and increasing reusable waste (i.e., setting criteria)	√		√	√	√	√		√	√	√	√		√			√	√				√		√	√	√	√	√			√		√		√	√			√				√		**24**	**53.3**
24		Financial rewards and incentives for the effectiveness of decreasing and reusing waste			√	√			√		√	√	√	√	√	√					√	√	√				√			√			√						√			√	√		√	**19**	**42.2**
25		Contractor's current waste assessments score and future target					√	√	√		√	√	√							√	√					√										√				√		√				**12**	**26.7**

Table 2. The contractor's controlling factors contribute to effective CWM in building construction (continued)

No.	Categories	Factors/ Attributes	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	Number of studies	Number of studies in (%)
			(Ganiyu et al., 2020)	(Poon et al., 2004)	(Lu et al., 2010)	(Kabirifar et al., 2020)	(Tam, 2008)	(Ghaffar et al., 2020)	(Kabirifar et al., 2020a)	(Daoud et al., 2021)	(Wu et al., 2017)	(Osmani et al., 2008)	(Ajayi et al., 2015)	(Li et al., 2022)	(Janani et al., 2022)	(Jaillon et al., 2009)	(de Magalhães et al., 2017)	(Bossink et al., 1996)	(Ajayi et al., 2018)	(Fernández S. et al., 2010)	(Andersson et al., 2022)	(Ding et al., 2018)	(Udawatta et al., 2015)	(H. Yuan, 2013)	(Saheed O Ajayi et al., 2017	(Lu et al., 2021)	(Cha et al., 2009)	(Kolaventi et al., 2018)	(Newaz et al., 2022)	(Bao et al., 2020b)	(Wang et al., 2010)	(Yeheyis et al., 2012)	(Bakshan et al., 2017)	(Wang et al., 2014)	(Begum et al., 2009)	(Bao et al., 2021)	(Zhao et al., 2022)	(Doust et al., 2020)	(Menegaki et al., 2018)	Kolaventi et al. (2020)	(Umar et al., 2016)	(Yuan et al., 2022)	(Yuan, 2013)	(Ajayi et al., 2017)	(Zulu et al., 2022)		
27	Materials	Adequate protection of material transportation and handling (loading and unloading)	√	√	√	√	√	√	√	√		√	√		√	√		√						√	√		√	√			√	√				√		√					√			22	48.9
28		Adequate protection of different categories of materials during storage and stacking	√	√	√	√	√		√	√		√	√		√		√	√							√			√			√	√						√		√						18	40.0
29		Preventing ordering errors and ordering appropriate material sizes and quantities to avoid excess	√	√	√	√	√	√	√	√		√			√			√					√		√		√									√		√						√		17	37.8
30		Use of quality and durable, and standardized materials		√	√	√		√		√			√			√		√		√			√		√	√						√							√							14	31.1
31		Adopt Just in Time delivery (JIT) system	√	√					√	√	√			√				√							√				√	√	√	√				√										13	28.9
32		Strong security at the project site (i.e., prevent the loss of materials)		√	√	√	√			√		√				√		√		√					√		√					√						√								14	31.1
33	Equipment/ tool	Use and familiar with the application of BIM	√	√	√	√	√	√	√	√	√		√	√		√			√		√		√	√	√					√		√				√					√				√	22	48.9
34		Use and familiar with other related information technologies	√	√	√	√	√	√	√	√	√		√	√		√			√		√		√	√	√					√						√					√				√	21	46.7
35		Availability and quality of equipment (tools, machines, and vehicles)		√	√	√					√			√				√			√			√						√	√										√					11	24.4
36		Use and familiar with the equipment		√		√		√	√	√	√			√		√					√			√																	√					11	24.4
37		Use metal scaffolding and formwork (e.g., rent them from professional suppliers)			√	√	√				√			√							√	√		√										√								√				10	22.2
38	Construction method and process	Adequate site space and the site layout are cleared for materials movement	√	√	√	√	√	√	√	√	√	√	√		√	√	√	√	√	√				√	√		√	√	√	√	√	√			√	√		√		√			√	√		31	68.9
39		Set up separated bins by waste type and sort out individual waste by type from mixed waste at the site with notice categories	√	√	√	√	√	√	√	√	√			√	√					√	√	√		√		√	√	√	√		√	√				√			√	√	√		√	√		27	60.0
40		Efficient use of materials and minimizing the uneconomical cutting shapes and length (including rebar schedule and materials lists to be reused)	√		√	√	√	√		√			√			√	√	√	√	√			√	√	√	√		√	√		√	√	√		√			√				√	√			25	55.6
41		Effective implementation of a waste management plan		√			√	√	√		√	√		√	√		√	√		√	√	√						√	√		√	√	√				√	√	√		√	√				23	51.1
42		Store waste in easily accessible areas	√	√	√	√	√	√		√		√				√	√			√					√	√	√	√	√	√	√				√	√		√		√				√		23	51.1
43		Bins are installed on every floor	√		√	√	√	√	√	√	√			√	√					√	√	√		√	√			√	√		√	√							√	√	√					22	48.9
44		Adopt prefabricated structural elements	√	√	√		√	√	√	√		√		√		√			√			√	√	√	√		√							√			√			√	√	√				21	46.7
45		Adopt preassembled components such as bathroom & kitchen pods	√	√	√		√	√	√	√		√		√		√			√			√	√	√	√		√							√			√			√	√	√				21	46.7
46		Minimize waste from application processes (i.e., overpreparation of mortar)	√	√	√		√	√									√	√	√	√	√			√		√		√	√													√				15	33.3
47		Minimize rework at the construction site	√					√	√						√		√					√			√		√			√					√		√					√				12	26.7
48	Documentation	Variation orders minimization	√	√					√	√		√	√				√	√	√			√		√	√									√				√						√		15	33.3
49		Document control of CWM with effectiveness (amounts, kinds, etc.)	√		√	√						√			√	√			√	√			√			√	√	√	√										√	√						15	33.3
50		Design changes during construction minimization	√	√								√	√				√	√	√					√										√				√						√		11	24.4
51		Shop drawing detailing errors preventing	√	√								√					√	√	√																			√								7	15.6
52		Professional quality management and certification (e.g., ISO, GREEN, etc.)						√									√			√	√																		√						√	6	13.3
53		Lesson learned repository on CWM	√												√			√		√										√				√												6	13.3
54		**TOTAL**	**37**	**35**	**34**	**34**	**34**	**33**	**33**	**32**	**32**	**31**	**29**	**29**	**29**	**28**	**27**	**26**	**25**	**25**	**24**	**24**	**23**	**23**	**22**	**22**	**21**	**21**	**20**	**20**	**19**	**19**	**18**	**18**	**17**	**17**	**17**	**17**	**17**	**15**	**14**	**14**	**12**	**11**	**10**		

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