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TOPICAL REVIEW

Enhancing construction waste management in New Zealand: Lessons from Hong Kong and other countries

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Abstract

Global construction waste (CW) poses escalating environmental, social, and economic challenges. While New Zealand grapples with a dearth of research on optimal construction waste management (CWM) techniques, it stands to gain from the comprehensive practices employed in regions like Hong Kong. Drawing from the extensive literature on CWM practices in Hong Kong and other countries, this study seeks to furnish New Zealand's construction professionals and policymakers with invaluable insights. Key findings illuminate the determinants of successful CWM, the motivations steering stakeholder behaviour towards CW reduction, the transformative potential of public policy, and innovative enhancement strategies. The research underscores the instrumental roles of green building and big data in CW curtailment, delving into the attendant challenges and rewards. By assimilating lessons from these international paradigms, New Zealand is poised to refine its CWM, catalysing a shift towards a more sustainable construction landscape.

1. Introduction

Waste is a rising concern for its negative environmental and public health impacts. These impacts are mainly related to the waste composition, which may consist of hazardous materials being dumped in landfills, causing soil contamination, pollution to groundwater resources, and an increase in carbon emissions (UNEP 2015). According to the World Bank (2018), the current rate of global waste generation is predicted to rise by 70% in 2050. Most of the generated waste is currently discarded in landfills with a minimal amount to be reused or recycled (Turkyilmaz *et al* 2019).

The construction industry is liable for a considerable amount of total waste generated globally, with approximately 13%–30% of waste in landfills (Thongkamsuk *et al* 2017). Construction waste (CW) is a severe concern for its negative impacts, and the world will benefit exceptionally from managing it. Ding *et al* (2018) described some benefits of construction waste management (CWM), including increasing resource efficiency, total greenhouse gas emission depletion, and saving landfill space. Improving waste management practices in the construction sector requires global efforts to maintain a safe environment, sustainable development, and efficient use of resources. Significant studies have been conducted in the construction industry to understand the current CWM practices and for future improvements.

The construction industry is developing rapidly in New Zealand, retaining the highest annual growth rate over the last five years from 2015 to 2019 of all other industries (StatsNZ 2019). The National Construction Pipeline Report commissioned by the Ministry of Business, Innovation, and Employment (MBIE) (2019) estimated the growth to gradually increase by 2021 in response to a population growth demand in residential, non-residential, and infrastructure work. The construction work activity in 2017 in the residential building rose by 14.2% to \$3.3 billion (MBIE 2017). In addition, non-residential buildings recorded an increase of 5.1% to \$1.7 billion (MBIE 2017). There have been a substantial number of construction activities around New Zealand recently; for instance, residential building and infrastructure projects in Auckland, post-earthquake rebuilding in Canterbury, and the construction development for earthquake-prone buildings in Wellington. Consequently, CW is a growing issue in New Zealand, generating 50% of all waste (Level 2020). Auckland, the largest region with 35% of the total population in New Zealand (StatsNZ 2018), has encountered significant obstacles in managing CW arising from the growth in infrastructure reinforcement works, greenfield and brownfield development, extensive long-lasting projects, and housing expansion (Auckland Council 2018).

1.1. CW in New Zealand

There is a lack of research on CW in New Zealand, as only a few recent papers were found. Keywords including 'construction waste' and 'New Zealand' were used in the Scopus and Google databases to locate studies on this topic. After refining the results, only five relevant papers were found by reading the titles, abstracts, and conclusions. Mainly, the studies focused on the prefabrication process, the volume of waste generation, disaster waste recovery, and exploring the use of new materials. Ghose *et al* (2017) examined the environmental impacts of refurbishment construction projects as one of the most frequently used practices in New Zealand. Initially, they compared on-site refurbishment strategies associated with waste minimisation practices and the use of materials with recycled elements. Results showed that enhancing on-site practices such as reusing materials and waste recovery would minimise waste more efficiently. However, there was insufficient data about recycled or reused materials regarding quality, sourcing location, and availability in the New Zealand market. Hence, the study suggested that engaging stakeholders in the primary stages of the project, such as design and material selection, will enhance the material recovery and reuse on-site. Also, the study highlighted CW generated from the refurbishment projects as one of the significant concerns negatively affecting the environment. Thus, Ghose *et al* (2017) urged policymakers and stakeholders to define and enhance CWM practices as an equilibrium element for these environmental impacts.

Luo and Shahzad (2020) analysed perspectives from professionals and stakeholders with practical experience in the construction sector in New Zealand to examine the impacts of prefabrication construction projects on waste generation. The results indicated the effectiveness of adopting prefabrication for CW minimisation. However, it only works with adequate governance and quality control in the prefabrication process. An alternative solution in prefabrication was introduced by Harris *et al* (2019). The study evaluated using prefabricated material and structurally insulated panels (SIPs) in the New Zealand construction industry to increase thermal efficiency in buildings and enhance CW reduction on-site. However, the study did not indicate the effectiveness of SIPs in CW reduction in New Zealand. Not having enough knowledge and experience about SIPs was revealed as the most significant challenge. The relationship between CWM and disaster recovery planning was researched by Domingo and Luo (2017). The research highlighted an urgent need to manage the massive volume of CW generated from demolition and reparation works in affected properties in Canterbury. Brown and Milke (2016) identified stakeholders' challenges in recycling disaster waste. These two studies only focused on earthquake events.

1.2. New Zealand and Hong Kong

According to MBIE (2018), New Zealand's construction sector contributes 6% of the total GDP. Similarly, the construction industry is significant in Hong Kong's economy, accounting for 4.5% of the total GDP (CSD 2018). While this economic impact may seem optimistic, the substantial amount of CW generated has led to environmental concerns for both the New Zealand and Hong Kong governments.

Lam *et al* (2019) identified the primary objectives for Hong Kong's government strategy as follows: (1) minimise waste generation; (2) expand the use of reuse and recycling practices; (3) reduce the amount of mixed CW at landfills. In comparison, New Zealand's waste strategy goals (MfE 2023) include: (1) minimising the harmful impacts of waste; (2) enhancing resource use efficiency. However, there has been a lack of efficiency in achieving these goals in both New Zealand and Hong Kong. One common reason is the imbalance of authority between the public and private sectors in managing CW.

In both countries/territories, the initial process typically involves directing CW to either public fills or landfills, depending on the types of waste. According to the Hong Kong Government GovHK (2019), inert CW is reused, while non-inert CW is sent to landfills. Similarly, in New Zealand, most generated waste consists of inert materials like rubble and concrete, which are recovered and sold as aggregate, while the remaining CW is sent to landfills (Wilson *et al* 2017). Wilson *et al* (2017) stated that at least half of the generated waste could be diverted from landfills and clean fills by sorting waste. Hong Kong achieved a recycling rate of 92% by enhancing its waste sorting strategy (Environmental Protection Department (EPD) 2019).

Prefabrication is widely promoted in both Hong Kong and New Zealand as an effective method to address the challenges of CW generation. However, barriers and limitations exist in assessing its effectiveness in both countries. Additionally, organisations in New Zealand and Hong Kong have embraced the global trend of green building (GB), which involves constructing buildings with minimal negative impacts on human and environmental health while maintaining high efficiency (World Green Building Council (WGBC) 2020).

These points highlight the similarities between the two countries/territories. However, compared to New Zealand, which has only five articles on CW, Hong Kong ranks among the top three countries/territories regarding published research articles on CW, following China and Malaysia (based on a search using the keyword 'construction waste' on Scopus). New Zealand could improve its current CWM practices by learning from Hong Kong's research. This research aims to offer a comprehensive literature review of recent CW studies, mainly in Hong Kong, to provide insights into CWM practices that could offer valuable lessons for CWM in New Zealand. The specific objectives of this study are: (i) Identify factors affecting CWM; (ii) explore stakeholders' behaviour in CWM; (iii) investigate the roles of enhanced public policy in CWM; and iv) examine innovative methods and techniques in CWM. The research results are then confirmed with other countries' research on CW.

CW is a growing global concern with significant environmental, social, and economic implications. The construction industry has recognised the importance of addressing CW to mitigate its impact. Building knowledge about the problem is essential, particularly in areas with limited research, such as New Zealand. This study contributes to the CW knowledge in New Zealand by providing a literature review from Hong Kong and other countries to share lessons and insights with professionals in the construction industry and policymakers.

While numerous studies have explored CWM in diverse contexts, a notable gap exists in understanding the comprehensive synthesis of global practices and their applicability to New Zealand's unique landscape. The primary contributions of this study, detailed further in the conclusion, are to bridge this gap, offering nuanced insights into stakeholder behaviour, policy implications, and practical tools.

2. Research methodology

This research adopted a blended approach of systematic and narrative literature reviews. Literature reviews provide structured summaries of extant literature on specific topics and enable the identification of research gaps (Wee and Banister 2016). Systematic reviews are characterised by their comprehensive, transparent, and unbiased nature, synthesising selected studies in alignment with the research's aims, questions, and objectives (Thomé *et al* 2016, Siddaway *et al* 2019). The systematic review method was primarily employed to examine New Zealand and Hong Kong studies. Subsequently, a narrative review was utilised to consolidate the results from Hong Kong studies, offering a broader understanding of the topic and highlighting the key themes and findings. This dual approach ensures both precision and breadth in examining the available literature.

The systematic literature search commenced with the Scopus database, renowned for its peer-reviewed literature and rigorous standards ensuring quality and bias minimisation (Kulkarni *et al* 2009, Bergman 2012). Search parameters, in line with the research objective, combined the keywords 'construction waste' with 'New Zealand' or 'Hong Kong', see figure 1. For the papers, strict inclusion/exclusion criteria were implemented: English language, publications from 2016–2021, and journal articles. This strategy is rooted in the need for contemporary data, the dominance of English in academic discourse, and the research's geographic specificity (Yoshii *et al* 2009, Drubin and Kellogg 2012). This strategy identified 5 papers for New Zealand and 37 for Hong Kong.

The chosen method for data analysis in this review is thematic analysis. Defined as the process of discerning, correlating, and interpreting thematic patterns within a dataset, thematic analysis offers a structured approach to data interpretation (Maguire and Delahunt 2017). Its core purpose is to derive substantive insights from the data in context with the research query, ensuring that findings are rooted deeply in the evidence presented (Vaismoradi *et al* 2013). Barnett-Page and Thomas (2009) highlighted the robustness of thematic analysis as a research instrument, emphasising its potential to offer actionable recommendations for both practitioners and policymakers. Such an approach ensures that the insights gleaned are both informative and applicable in real-world scenarios.

3. Results and discussion

Figure 2 presents the structure of the section, delineating three principal categories: (1) Factors affecting CWM in Hong Kong, (2) Factors affecting CWM in other countries, and (3) Lessons for New Zealand CWM.

3.1. Factors affecting CWM in Hong Kong

3.1.1. Policy and regulations

Lu *et al* (2016) defined CW public policy as an all-encompassing term that includes ordinances, regulations, codes of conduct, and initiatives introduced by the government or government-related agencies. The study

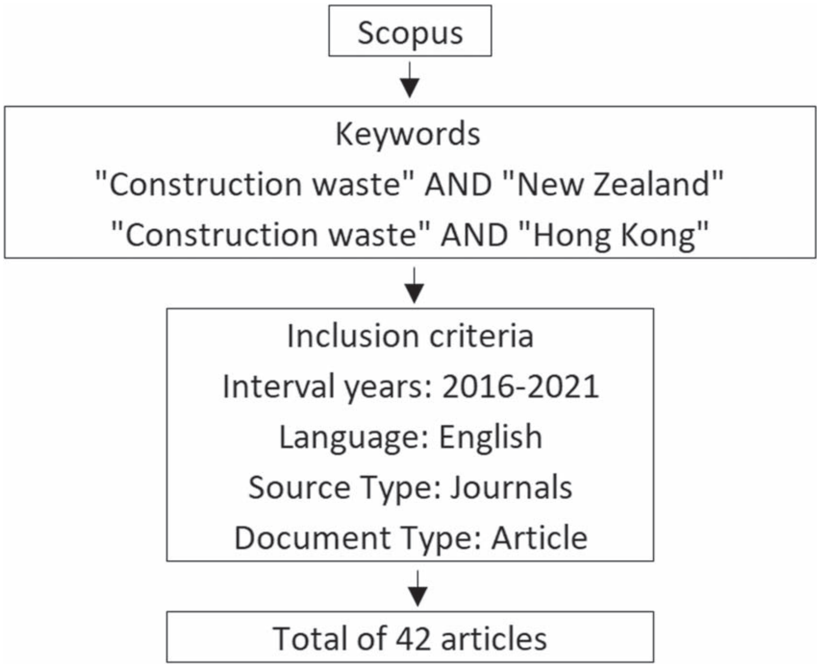

Figure 1. Search criteria.

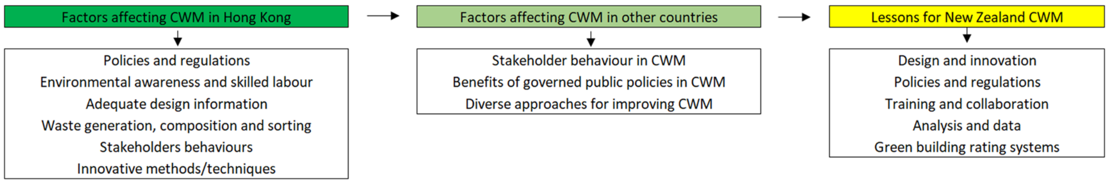

Figure 2. Outline of results and discussion.

concluded that public policies need enhancement through government enforcement of acts and laws. For better CWM performance, policymakers should review and improve existing regulations. Mak *et al* (2019) highlighted measures to achieve regulatory effectiveness, such as executability, fulfilling, and overseeing. These measures relate to the ability to apply regulations on the ground, integrating policies and regulations, and the government's role in ensuring exact implementation, respectively.

Regulatory compliance has been proven to reduce the amount of generated CW and support the waste recycling market (Mak *et al* 2019). Lu (2019) emphasised the importance of enforcing the CW disposal charging policy in Hong Kong, significantly reducing CW. Regulations enforcement also improved practitioners' behaviour in CWM. Lu *et al* (2019) pointed out the need for a policy review to improve the crediting system in GB. Xu *et al* (2020) also mentioned enhancing regulations to improve CWM efficiency in Hong Kong's private sector.

Mak *et al* (2019) identified the waste disposal charging scheme (WDCS) as an effective tool for reducing waste and minimising environmental burden. Hong Kong enacted the CW disposal charging scheme policy to enhance CWM effectiveness (Lu *et al* 2016, Hossain *et al* 2017). Under this policy, contractors are allowed to dispose of CW in government-managed facilities for a specific fee. Zhang *et al* (2018) described this scheme's process as sorting the CW and dumping it into designated landfills for reuse, recycling, or disposal. Hossain *et al* (2017) mentioned that the initial CW charge underachieved its aim of motivating better on-site practices to reduce waste. Consequently, Hong Kong authorities later increased the fee (Wu *et al* 2019). Lam *et al* (2019) agreed that raising the CW charging fee would encourage stakeholders to adopt effective CWM strategies.

However, Mak *et al* (2019) argued that maintaining a reasonable charge is the crucial factor in effective CWM that would incentivise stakeholders to change their behaviour. Zhang *et al* (2018) highlighted the purpose of implementing the charging scheme in Hong Kong as a means to provide economic incentives for practitioners to enhance waste minimisation strategies.

The enforcement and effectiveness of regulations and charging schemes play a significant role in driving better CWM practices. By reviewing and enhancing existing policies, Hong Kong and New Zealand authorities can learn valuable lessons from each other to improve their respective CWM systems and encourage stakeholders to adopt more sustainable and efficient practices.

3.1.2. Environmental awareness and skilled labour

Lu *et al* (2016) noted that heightened environmental awareness concerning the adverse impacts of CW led to improved CWM performance. For instance, clients' commitment to environmental protection influenced contractors to adopt efficient CWM practices. The difference in CWM performance between the public and private sectors can also be attributed to practitioners' varying levels of awareness.

Lu *et al* (2018) identified the lack of information due to poor practitioner awareness in on-site data collection. The study underscored the importance of demonstrating the proven benefits of CWM in GB projects to stakeholders, including investors, owners, designers, consultants, and contractors, to encourage CWM practices and raise awareness.

Xu *et al* (2020) emphasised that firms' environmental awareness, environmental leadership, and corporate social responsibility contribute to efficient CWM. Lam *et al* (2019) added that skilled labour is crucial in proper on-site CW sorting, while designers can enhance design constructability.

Zhang *et al* (2018) identified the shortage of experienced designers, suppliers, and contractors as barriers to CW minimisation practices. The study delved into design flexibility and designers' competency as significant barriers to adopting prefabrication. It also highlighted design inflexibility, particularly the inability to accommodate changes during construction when incidents occur, as the top barrier to prefabrication.

Environmental awareness among stakeholders and skilled labour are key factors in improving CWM performance. Enhancing practitioners' awareness and fostering environmental leadership and corporate social responsibility can further contribute to efficient CWM practices across various sectors in both Hong Kong and New Zealand.

3.1.3. Adequate design information

Lam *et al* (2019) emphasised the importance of adequate design information in efficient CW quantification. Accurate design information allows project managers to schedule better materials supply and delivery, frees up on-site space for proper sorting and provides a more precise estimation of CW regarding recycling and cost benefits. Furthermore, Lam *et al* (2019) noted that the information obtained from waste quantification, such as identifying the most wasteful material, is valuable for designers to consider alternatives. The study also underscored the significance of CW information for contractors and developers in planning transportation, waste charge costs, and labour allocation.

Wu *et al* (2019) identified the lack of accurate information and challenges in data collection, such as details related to CW quantification or composition, as barriers to achieving efficient CWM. Moreover, Lu *et al* (2019) highlighted the crucial role of data collection in scoring CWM-related credits in GBRSs. The study confirmed that data collection documentation, authentication, and verification are barriers to effective CWM performance in GB. One challenge is the gap in reporting from contractors to GB consultants, resulting from a lack of coordination. This adds pressure on GB consultants and increases uncertainty in achieving GB credits.

Ensuring adequate design information is critical for effective CWM. Hong Kong and New Zealand can work towards more efficient and sustainable CWM practices by addressing data collection challenges, improving CW-related information accuracy, and enhancing coordination between contractors and GB consultants.

3.1.4. Waste generation, composition and sorting

Collecting information about CW regarding quantity and composition is essential for effective CWM planning and decision-making (Lam *et al* 2019). CWM strategies can be tailored to reduce specific types of materials and provide better forecasting to allocate the cost and resources needed (Lu *et al* 2016, Hossain *et al* 2017, Wu *et al* 2019). Thus, more efficient CW sorting provides a detailed list of CW composition information, leading to highly efficient CWM. Arguably, Lu *et al* (2016) pointed out that CW generation forecasting is the most challenging to achieve because of the high uncertainty in construction projects. Lu *et al* (2018) mentioned the waste generation rate (WGR) as a measuring tool for waste generation in a construction project.

Wu *et al* (2019) identified waste sorting as an essential factor in effective CWM, highlighting its purpose in understanding and collecting information about CW generation and composition. A critical element in waste sorting is information accuracy in measuring waste generation and quantification (Lam *et al* 2019). Waste composition depends on the stage of the construction project, and CW is classified into inert and non-inert based on its forming elements (Lam *et al* 2019). Inert CW, mainly consisting of soil, rubble, and concrete, can be reused in land reclamation and site formation works. Non-inert CW, the largest in Hong Kong, includes wood, timber, and metal. Hossain *et al* (2017) observed that significant environmental benefits are associated with a higher amount of non-inert waste because of its higher potential to be recycled.

On-site and off-site sorting methods impact CWM as well. Hossain *et al* (2017) indicated that on-site sorting requires waste separation on-site to prevent CW from being mixed. On-site sorting has fewer environmental impacts than off-site sorting due to fewer transfer trips and a higher reusing and recycling potential. The study anticipated substantial environmental improvement if on-site sorting increased. Wu *et al* (2019) confirmed this finding but argued that on-site sorting depletes resources such as labour and space. Zhang *et al* (2018) also highlighted 'space' as a challenge to on-site sorting in Hong Kong. Hence, limited space is considered a barrier to storing recycled materials and adopting CW minimisation practices. Consequently, off-site sorting is more feasible in Hong Kong due to limited land spaces.

Waste generation, composition, and sorting practices significantly influence effective CWM. Hong Kong's construction industry faces unique challenges due to limited space availability, making off-site sorting more feasible. In contrast, depending on project-specific circumstances, New Zealand's industry may benefit from different approaches. In both cases, accurate information about waste generation, composition, and sorting is critical to optimise CWM strategies, minimise environmental impacts, and allocate resources efficiently.

3.1.5. Stakeholders behaviours

Various factors, including the type of project, cost impact, time constraints, and policy and regulations, influence stakeholders' behaviour in CWM. Lu *et al* (2016) found that contractors' CWM behaviour change with the nature of the project partnership (public or private), which affect resource allocation and monitoring. Client perception of environmentally friendly options also drive contractors' behaviour (Xu *et al* 2020).

Cost impacts, such as the expenses associated with on-site waste sorting, labour, transportation, and site rent, significantly influence contractors' decisions (Lu *et al* 2016, Lam *et al* 2019, Wu *et al* 2019). In some cases, the high costs of specific waste management practices, such as prefabrication, hinder their adoption (Zhang *et al* 2018).

Time constraints also play a critical role in shaping practitioners' behaviour. For instance, limited project duration in Hong Kong lead developers to prioritise project delivery over adequate CWM practices (Lu *et al* 2016, Zhang *et al* 2018, Mak *et al* 2019). Time-saving motives also drive illegal dumping behaviour, as offenders seek to avoid queues at waste disposal facilities (Lu 2019).

Policy and regulations affect stakeholder behaviour as well. Public policies, like waste charges, incentivise contractors to adopt the 3R reduction, reuse, and recycling practices to save on waste disposal fees (Lu *et al* 2016). Regulatory compliance is a top factor influencing stakeholders' recycling behaviour (Mak *et al* 2019).

Project type, cost impact, time constraints, and policy and regulations influence stakeholder behaviour in CWM. Addressing these factors in Hong Kong and New Zealand could lead to more effective CWM practices and better environmental outcomes. Enhancing stakeholder awareness and understanding of the benefits of efficient waste management, policy adjustments, and improved resource allocation may contribute to more sustainable construction practices in both regions. Encouraging collaboration between the public and private sectors and fostering innovation and technological advancements could help overcome existing barriers and facilitate progress in CWM.

3.1.6. Innovative methods/techniques

3.1.6.1. Big data

Big data, as defined by Lu *et al* (2016), is a large set of digital information that can be structured, semi-structured, or unstructured. When effectively utilised, it can offer valuable insights for decision-making and forecasting in CWM. The three measures that qualify a dataset as big data are volume, velocity, and variety (Lu 2019, Xu *et al* 2020). Minimising bias in big data processing is crucial for obtaining accurate insights (Lu *et al* 2016). The larger the dataset, the less biased it is likely to be. By analysing numerous projects over extended periods, big data offers a deeper understanding of CWM performance. However, challenges such as reasonability, relativeness, and data quality need to be addressed (Lu *et al* 2016, Lu 2019, Xu *et al* 2020).

Big data can enhance decision-making and waste forecasting (Lu 2019) by identifying patterns and behaviours related to illegal dumping (Lu *et al* 2018). Xu *et al* (2020) also emphasised its capability to uncover hidden behavioural patterns useful for more efficient decision-making. Furthermore, big data can be integrated with other CWM tools, such as on-site inspections, to provide accurate and realistic waste generation forecasts (Lu *et al* 2016).

The S-curve is an effective planning tool that leverages big data, representing cost, working hours, quantity, or other related measures as a function of project time (Lu *et al* 2016). The S-curve can forecast waste generation before or during project progression, providing valuable information for decision-making and monitoring. Implementing the S-curve has challenges, such as contractors potentially accelerating minor project activities and delaying major ones to meet project targets without penalties. Integrated the S-curve with additional project management tools can mitigate this risk.

Two common approaches to generating an S-curve using initial project information are schedule-based analysis and historical-data-based estimation. The schedule-based analysis approach derives the activity duration and progression, producing an asymmetrical S-curve due to data irregularity in actual practice. This approach is useful when there is a clear, detailed project plan. In contrast, the historical-data-based estimation approach relies on analysing information from completed construction projects, making it helpful in forecasting waste generation. Lu *et al* (2016) used CW big data in Hong Kong to generate the S-curve in their study, integrating it with another database containing contract sums, construction models, site addresses, and client-related information.

Big data offers valuable insights and can be an effective CWM decision-making tool. It enables the detection of patterns, forecasting waste generation, and identifying potential issues such as illegal dumping. By combining big data with other tools and methodologies, such as the S-curve and on-site inspections, stakeholders can make more informed decisions and improve overall CWM outcomes. However, addressing challenges such as data quality, reasonability, and relativeness is crucial to ensure accurate and reliable insights are drawn from big data analyses.

3.1.6.2. Green building

GB refers to a construction model that promotes the efficient use of resources and sustainable processes for environmental and human health benefits (Lu *et al* 2019). While GB is expected to impact CWM positively, some studies indicate that it may not reach its full potential. GB performance is evaluated by GBRSs based on critical criteria (Lu *et al* 2019). Lu *et al* (2018) found that scoring more credits in the GBRSs does not necessarily lead to better CWM performance. This is partly because the credits allocated to CWM performance in GBRSs are materials-focused and have minimal weight compared to other factors (Lu *et al* 2019). Illankoon and Lu (2020) added that CWM performance should include both material aspects and CWM-related credits.

The high costs of green materials, labour for managing waste, and low CWM credit weight in GBRSs can act as barriers to adopting GB (Lu *et al* 2016, Lu *et al* 2018, Lu *et al* 2019). Illankoon and Lu (2020) suggested that considering life-cycle costs, which include initial and actual expenses divided by the number of uses, may provide a more accurate picture of the cost feasibility of CWM in GB.

Stakeholder behaviour, driven by cost and other factors, can also affect GB and CWM. Lu *et al* (2019) identified factors such as lack of incentives, knowledge gap, reluctance to use reused or recycled materials, and complexity of documenting CWM practices. These factors can discourage stakeholders from pursuing GB credits related to CWM.

While GB can potentially improve CWM, several challenges must be addressed. These include allocating credits in GBRSs, cost feasibility, and stakeholder behaviour. By understanding and addressing these challenges, it may be possible to harness GB's potential to enhance CWM performance and contribute to a more sustainable construction industry.

3.1.6.3. Building information modelling (BIM)

BIM is a cutting-edge technology that comprehensively harnesses data to analyse, simulate, and visualise a building throughout its life cycle (Zhang *et al* 2018). It has gained widespread acceptance in the construction industry, contributing to increased efficiency, cost reduction, and the promotion of sustainability. BIM's impact on CWM is especially significant, as it helps address challenges associated with prefabricated buildings' design, production, assembly, and maintenance processes (Zhang *et al* 2018).

BIM plays an essential role in CWM by streamlining waste minimisation practices during fabrication. It achieves this by enabling efficient logistics management, which is invaluable for cost prediction and gathering data on fabricated materials. This comprehensive approach to logistics management ensures that resources are allocated effectively, minimising waste generation throughout the construction process. Moreover, BIM can identify potential waste-generating elements during the design stage, allowing stakeholders to make informed decisions and implement changes before construction begins. This proactive approach to waste management significantly reduces material costs, boosts on-site quality, and allows for greater design flexibility (Zhang *et al* 2018).

3.2. Factors affecting CWM in other countries

Effective CWM depends on several critical factors. Lu and Yuan (2010) identified important aspects of waste management regulations, methods, knowledge about CWM, low-waste building technologies, fewer design variations, research and development, and professional training. Ajayi *et al* (2015) argued that waste prevention methods, such as designing out waste, are more effective than waste treatment. The study emphasised the importance of increasing knowledge and awareness of waste management competency among professionals in the construction sector.

On-site management practices significantly influence waste minimisation, as Ajayi *et al* (2017) explored. Factors like adequate design, effective waste sorting systems, contractual provisions, and proper logistics management were found to be essential. Meanwhile, Hasmori *et al* (2020) categorised common on-site CWM practices into five management groups: human resources, material and equipment, construction methods, administrative, and regulation. The study concluded that raising awareness and knowledge of CWM among workers, implementing professional use of construction materials, efficient waste separation, standardising design and material, and enforcing off-site handling processes and techniques are crucial for effective CWM.

Wang *et al* (2014) focused on critical factors for effective CW minimisation in the design phase. They emphasised the importance of large panel metal form-works, increased use of prefabricated elements, fewer design variations, modular design, investments in waste reduction, and economic incentives. Chinda (2016) highlighted the factors affecting CW recycling decisions, including economics, market and site activities, and environmental considerations. The study found that market and site activities were the key factors in waste recycling decision-making, followed by economic factors and the potential benefits of building an environmentally friendly reputation.

In summary, the most critical factors in minimising CW include design phase practices, governmental regulations and policy enforcement, professional knowledge and awareness of CWM, and CW sorting methods. The construction industry must train and inform workers, designers, contractors, and other practitioners of best practices in CW minimisation to achieve effective CWM.

3.2.1. Stakeholder behaviour in CWM

Stakeholder behaviour plays a crucial role in effective CWM. Wu *et al* (2017) found that economic feasibility and government regulations determined the contractor's decisions regarding CWM in China. Similarly, Li *et al* (2018) investigated contractor employees' behaviour using an extended Theory of Planned Behaviour model, highlighting the importance of training programs, enforcing CW policy, and raising public awareness for improved CWM.

Bakshan *et al* (2017) classified influential factors of workers' behaviour into private and corporate groups. Raising awareness of construction waste's environmental and economic impacts influenced workers' attitudes. Yang *et al* (2020) explored construction workers' behaviour towards waste reduction practices, identifying reactive, prioritisation, and preventive actions as crucial factors for effective CWM. Li *et al* (2015) emphasised the role of designers' behaviour in developing designs that maximise waste management efficiency. Raising designers' awareness and knowledge of waste minimisation practices through policy enhancement, training initiatives, and legislation is vital. Yuan (2013) highlighted the government's role in policing CWM in China, suggesting tactics such as enacting comprehensive regulations, conducting inspections, and investing in research and development.

Liu *et al* (2019) compared CW minimisation behaviours in China and the USA, emphasising the importance of government oversight and enforcement of laws and regulations. The study also highlighted the significance of raising labour knowledge and professional skills in waste minimisation practices. De Magalhães *et al* (2017) underscored the crucial role of design professionals' behaviour and design choices in influencing CW generation, emphasising the need for increased knowledge and adoption of best practices in CWM among designers.

Stakeholder behaviour, encompassing contractors, workers, designers, and government entities, plays a significant role in effective CWM. Raising awareness, improving training, and enforcing regulations are crucial steps towards sustainable waste management practices in the construction industry.

3.2.2. Benefits of governed public policies in CWM

Governed public policies significantly improve construction waste management (CWM). Yeheyis *et al* (2013) demonstrated that an integrated framework, which includes reduce, reuse, and recycle principles, led to reduced waste and improved sustainability indicators for CW composition. Ajayi and Oyedele (2017) identified a set of controls to enhance waste management efficiency, including reward systems, targeting the design phase with policies, and increasing penalties for non-compliance.

Nasidi *et al* (2016) analysed the moderating effect of government policy on company management levels and found that a high level of formalisation led to improved professionalism and effectiveness in CWM. Jin *et al* (2017) emphasised the importance of government policies and strategies in improving CW treatment and recommended considering critical factors related to CW treatment decision-making.

Doan and Chinda (2016) discussed the government's role in encouraging recycling programs in construction firms, highlighting the benefits of implementing landfill levies and easing taxes on firms wishing to start recycling programs. Rodríguez-Robles *et al* (2015) stressed the need for stricter regulations and clearly defined guidelines for managing CW reuse and recycling in Spain.

Bains *et al* (2019) identified a set of policy controls to maximise CWM efficiency, which need to be adjusted according to the country's economic, technical, and social systems. Essential rules include landfill bans, taxing primary construction materials, limiting illegal waste dumping, and public sector interest in practising CW minimisation.

Effective government regulations and public policies improve CWM. Key measures to achieve maximum benefits include government supervision, an integrated framework with rewards, taxes, and penalties, and clear communication between government authorities and private practitioners in the construction sector.

3.2.3. Diverse approaches for improving CWM

Gálvez-Martos *et al* (2018) observed the diversity in waste treatment methods in the European market, recommending a circular economy strategy based on policy and management practices improvement. Udawatta *et al* (2015) identified five factors for enhancing waste management: teamwork, strategic planning, adequate design, breaking traditions, and life cycle management. The study emphasised stakeholder engagement and government regulations for effective CWM.

Gangolells *et al* (2014) examined common waste management practices in construction projects and found that on-site tidiness, adequate warehousing, and site waste managers were the most common. The study revealed that construction firms align with the government's aims of initiating fine and reward systems and environmental education programs.

Camgöz Akdağ and Beldek (2017) proposed adopting green supply chain management for minimising construction waste, emphasising the importance of using minimal raw materials and recovery processes. Laquatra and Pierce (2009) argued that green building practices could improve CWM by expanding practitioners' knowledge and skills and recommended raising awareness about the environmental impacts of construction waste.

Hao *et al* (2021) and Tam and Hao (2014) explored the use of prefabricated materials as a method to reduce construction waste. Both studies found that prefabrication significantly reduced waste but faced obstacles such as prolonged waiting times for materials and a shortage of skills and knowledge in the construction sector.

Various approaches for improving CWM include stakeholder management, economic feasibility, efficient material use, green building practices, and prefabrication. Effective implementation requires collaboration between the construction sector, government policies, and environmental awareness.

3.3. Lessons for New Zealand CWM

The results from overseas studies, including those from Hong Kong, demonstrate similarities in effective CWM practices, emphasising the universal nature of challenges and solutions in this field. These findings can serve as valuable lessons for New Zealand as it seeks to improve its CWM strategies. Regulations, design practices, professional knowledge, waste sorting methods, stakeholder behaviour, and governed public policies contribute to effective CWM across different regions. The diverse approaches identified, such as stakeholder management, economic feasibility, efficient material use, green building practices, and prefabrication, showcase the importance of collaboration between the construction sector, government policies, and environmental awareness. By learning from these international examples, New Zealand can adopt and adapt the best practices to suit its unique context, ultimately enhancing its CWM performance and promoting a more sustainable construction industry.

Specifically, the following are the lessons learned from improving CWM:

- Design and innovation

i. Zero Waste Vision: Traditional construction methodologies often revolve around entrenched practices that resist change. While commendable, Hong Kong's effort in managing construction waste on-site encountered challenges regarding economic sustainability in the journey towards a reduced waste paradigm (Bao *et al* 2020). For New Zealand, the challenge lies in achieving reduced waste and ensuring that the path towards it is economically sustainable.

ii. Innovation Incentives: Incentive structures, especially those encouraging prefabrication as a form of innovative construction methodology, have shown potential in driving innovation in the industry (Patil *et al* 2021, Su *et al* 2021, Tan *et al* 2023). Yet, the broader perspective on economic incentives indicates a potential risk of these becoming mere symbolic gestures without creating real impact (Shen *et al* 2021). New Zealand's diverse construction landscape necessitates a comprehensive incentive structure, catering to both small-scale contractors and large-scale developers.

- Policies and regulations

i. BIM Integration: While technologies like BIM hold potential, on-the-ground efficiency can differ from theoretical models due to factors like training gaps and reluctance to change (Majzoub *et al* 2023, Moradi and Sormunen, 2023). For New Zealand, this signifies the need for a more organic, bottom-up BIM adoption.

ii. Realistic Policies: One criticism often levied at policies derived from international best practices is their dissonance from local realities (Ismaeel and Kassim 2023, Peng *et al* (2023). New Zealand's regulations must be coherent with local needs, ensuring they are actionable rather than mere administrative exercises.

- Training and collaboration

i. Reimagining Qualifications: While introducing more advanced and targeted qualification criteria can optimise construction waste management outcomes, ensuring that such initiatives consider both new entrants to the field and existing professionals is crucial. Oluleye *et al* (2023) emphasised the challenges the construction industry faces in upskilling the existing workforce. Dainty *et al* (2005) suggested that any new qualification or training prerequisites should not alienate seasoned professionals but include them in the learning process. Aligning qualification criteria with comprehensive training programs can be instrumental, especially when coupled with economic incentives. Incentivising learning can lead to a heightened uptake of training programs and can be particularly effective in encouraging better waste management practices among workers (Botchway *et al* 2023). As New Zealand grapples with the dual challenge of upskilling its experienced workforce while integrating newcomers, it is essential to design advanced and inclusive qualifications. Taking cues from global trends, New Zealand must ensure a balanced approach, promoting advanced training without sidelining its seasoned construction professionals.

ii. Partnerships: The importance of aligning academic research with the actual needs of the construction industry cannot be overstated. Historically, there has been a gap between the theoretical frameworks proposed in academic literature and their on-ground implementation. Massaro *et al* (2021) highlighted the significant benefits of collaboration between academia and industry, particularly when it comes to innovations in practice. When it comes to waste management, such collaboration becomes even more vital. Construction professionals dealing with daily waste management challenges offer invaluable insights into the practical barriers to implementing best practices. Collaborative research initiatives involving academic researchers and on-field practitioners can provide more holistic solutions to CWM challenges, ensuring that recommendations are both innovative and feasible for real-world application. Bridging the academic-practical divide is especially pertinent for New Zealand. While theoretical frameworks offer a foundation, the on-ground insights from New Zealand's construction scene will ensure waste management strategies are innovative and aptly suited for the nation's unique landscape.

- Analysis and data

i. Quantifying the Intangible: Although cost-benefit analyses are crucial for evaluating the feasibility and long-term viability of construction projects, there remains a significant gap in adequately accounting for the intangible benefits inherent to construction waste management (Kang *et al* 2022, Kolaventi *et al* 2022). These benefits, ranging from socio-environmental considerations to worker morale and broader community endorsement, are not as readily quantifiable as traditional tangible costs. Despite their elusiveness, these intangible factors demand a holistic valuation approach, encompassing both socio-economic implications and ecological impacts. One potential avenue is the adaptation of broader assessment tools akin to the Human Development Index (HDI) or the Environmental Performance Index (EPI). Such indices could offer New Zealand an inclusive framework, ensuring that the nuanced benefits of waste management practices are not eclipsed by the overt, immediate expenses.

ii. Data's Double-Edged Sword: In the age of big data, the construction industry has heavily relied on data-driven decisions. However, potential pitfalls accompany such data dependencies. The classic issue, often referred to as the 'Garbage In, Garbage Out' phenomenon, reminds us that any analysis is only as good as the data it is based on (Munawar *et al* 2022). If the input data lacks quality, any resultant analytics or decisions would inherently be flawed. Consequently, while establishing a construction waste database is commendable, the emphasis must equally be on the data's authenticity, relevance, and integrity. For New Zealand, this underscores the significance of embedding rigorous data validation and verification protocols right from the inception of data collection.

- Green building rating systems

i. Cost Feasibility and Waste Reduction: Effective waste management in the construction industry is an environmental need and an economic imperative. GBRSs focusing on waste reduction often point towards sustainable construction materials that might seem costlier upfront. Ismaeel (2023) observed that investments in such materials often lead to long-term economic benefits because of reduced waste management costs and efficient resource utilisation. This presents a dual advantage for New Zealand: cost savings and diminished waste.

ii. Leveraging Practitioner Experience in Waste Management: An informed GBRS integrates the insights of those directly engaged in construction. They witness first-hand the generation and handling of waste. Lingard *et al* (2001) stated that regular feedback from practitioners aids in developing more efficient waste management practices. New Zealand could benefit from such a feedback-centric approach, tweaking GBRSs based on the challenges and opportunities identified by those on the ground.

iii. Market Availability and Waste Minimization: A GBRS that does not consider market realities can inadvertently contribute to waste. If advocated sustainable materials are not readily available, construction projects might resort to less sustainable alternatives, leading to more waste. Gelan (2022) and Raouf and Al-Ghamdi (2023) mentioned the alignment of GBRS guidelines with market availability, ensuring sustainability and waste minimisation. New Zealand's GBRS refinements should, thus, remain attuned to market dynamics, promoting materials and methods that are both sustainable and readily available.

4. Conclusion

This research provides a comprehensive literature review of recent CW studies, primarily focusing on Hong Kong's practices. The primary purpose of this investigation was to derive lessons from these studies that can offer valuable insights and applications for CWM in New Zealand. Through this lens, the research objectives were meticulously addressed:

i. Identification of factors affecting CWM: The study highlighted innovations in design, policies and regulations, and the significance of data reliability and analysis. Emphasising both tangible and intangible factors, it underscores the multi-faceted challenges faced by New Zealand in its pursuit of improved CWM.

ii. Exploration of stakeholders' behaviour in CWM: The research unearthed valuable insights into stakeholders' attitudes, notably the dual roles they play both as influencers and as respondents to policies, especially in the context of GBRSs. Their role becomes imperative in the successful implementation of waste management strategies.

iii. Investigation of enhanced public policy's role in CWM: The study explored the intricate dynamics of international policies, emphasising the importance of crafting New Zealand-specific regulations that resonate with local realities while leveraging global best practices.

iv. Examination of innovative methods and techniques in CWM: Pivoting around design and innovation, the role of technologies like BIM, and the crucial impact of training and collaboration, the research emphasised the importance of adopting and adapting innovative practices, especially in the New Zealand context.

This research broadens the current understanding of CWM by offering a distinct comparative perspective, drawing insights from Hong Kong and other nations to refine New Zealand's strategies and methodologies. The study paves the way for a more nuanced and effective approach to CW minimisation in New Zealand by delving into the drivers behind stakeholders' behaviours. The pivotal role of public policy in influencing CWM outcomes stands as a beacon for New Zealand's policymakers, urging the adoption of the presented actionable methods for a more streamlined and efficient framework. Further, by spotlighting green building techniques and big data, this research furnishes stakeholders with practical tools and a clearer trajectory towards tangible action. The comprehensive outline of potential challenges and rewards ensures New Zealand has a clear roadmap for successfully integrating these strategies.

A synergy of qualitative and quantitative on-site investigations is recommended further to enrich the understanding of CWM in New Zealand. Direct dialogues with construction industry practitioners and policymakers, through structured interviews, will elucidate the intricacies of day-to-day practices and challenges. Engagements with project managers, contractors, and developers will provide comprehensive insights into CWM stakeholders' behaviours and response strategies. Furthermore, a comparative study of policy adherence across varied construction projects can spotlight exemplary practices and areas warranting enhancement. A pivotal avenue for future enquiry remains the market dynamics concerning recycled materials in New Zealand, examining both the promotional strategies and existing impediments to their widespread utilisation.

Data availability statement

No new data were created or analysed in this study.

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