Construction & Demolition Waste Minimisation in New Zealand: Challenges and Remedies

Rohit Gade[1], Jeff Seadon[2] and Mani Poshdar[3]

[1] School of Future Environments, Auckland University of Technology, Auckland, New Zealand
[2] School of Future Environments, Auckland University of Technology, Auckland, New Zealand
[3] School of Future Environments, Auckland University of Technology, Auckland, New Zealand

Abstract. Construction and Demolition (C&D) waste contributes to half of the total landfill waste in New Zealand (NZ). Further, C&D waste is the largest waste stream in Auckland with 40% of waste going to landfill. This study adopts a mixed-method approach to collect and analyse data. In total, 37 semi-structured interviews were conducted with different groups from clients representative, contractors and policymakers and influencers categories. Subsequently, on-site observations on nine sites (construction, refurbishment and demolition- 3 from each) were conducted to validate the interview findings. The interviews and on-site observation provided remedy(ies) for each challenge: Waste minimisation clause in contracts (pre-design); client and contractor education (design); multiple bins and Toolbox meetings (construction); compliance to reuse and encouragement to clients and contractors (refurbishment); and technical and financial guidance and increase waste levy (demolition).
For efficient waste minimisation, actions from one group requires support from other two groups. For instance, if policymakers decides to fund community recycling centers, the client need to demand sustainable materials, and contractors needs to use them. This research is an attempt to contribute to United Nations's Sustainable Development Goal 12 that ensures sustainable consumption of resources by achieving the Target 12.5 (substantially reduce waste generation through prevention, reduction, recycling and reuse).

Keywords: C&D Waste, C&D Waste Minimisation Approaches, Waste Minimisation Framework.

1 Background

Waste generated due to construction and demolition work from any building, including excavated soil from contaminated land is considered as Construction and Demolition (C&D) waste (MfE, 2015). C&D waste composition typically includes concrete, plasterboard, wood, steel, brick, cardboard, metal, plastic, and glass. In 2018, C&D waste became the largest waste stream in NZ, with 20 % of all waste going to landfill and 80% to Cleanfill (NZTA, 2019). Further, in 2020, 3.6 million tonnes of C&D waste was generated in NZ (MfE, 2021). The Auckland Construction Industry (CI) contributed 20% to the total C&D waste and is projected to grow at around 3% per

S. Singh et al. (eds.), *Proceedings of the Smart Sustainable Development Conference 2025 (SSD 2025)*, Atlantis Highlights in Sustainable Development 2,
https://doi.org/10.2991/978-94-6463-720-5_5

annum (Carpenter, 2020). C&D waste disposal increased concerns about environmental stability, economic growth and living standards of society (MfE, 2009). As a result, waste minimisation approaches were researched and implemented.

The waste minimisation approaches are classified under three categories: Waste Management Hierarchy; Guidelines and Regulations; and Tools. The waste management hierarchy was introduced in NZ in the early 90s (MfE, 1997). It includes different waste management techniques such as Reduction, Reuse, Recycle, Recover, Treat and Dispose or residual dispose. Reduction and Dispose are the extreme ends of hierarchy. The former provides environmental benefits, while the latter damages environment (MfE, 2009).

The conservation of the environment through guidelines and regulations has been an interest of the NZ government for decades (Nathan, 2007). For instance, Resource Management Act (RMA, 1991), Building regulations (Building Act, 1991), landfill guidelines (MfE, 2000), Cleanfill Guidelines (MfE, 2002) and Waste Management Act (WMA, 2008). Further, there are few non-governmental organisations, such as BRANZ and NZGBC who has own C&D waste minimisation guidelines (BRANZ, 2014; NZGBC, 2014). These guidelines covers topics from project tendering to the deconstruction stage (BRANZ, 2014, 2019).

CI practitioners uses different waste minisation tools such as resource routing calculator, waste management plan, recycling directory, and waste transfer form (BRANZ, n.d.). In addition, successful attempts have been made to minimise C&D waste through Lean Construction, Supply chain Management, Building Information Modelling (BIM) and Simulation tools (Vilasini, 2014; Zaeri, 2017).

Further, Artificial Intelligence (AI) can be used to minimise waste through precise design for cut-offs, real-time waste tracking, early resource optimisation plan, etc. AI uses methods such as Machine learning (regression analysis), Artificial Neural Network, Genetic Algorithm (Bang & Andersen, 2022). Other technologies such as blockchain is used to effective information management to minimise waste. Blockchain streamline the process (design to disposal) by optimizing resource consumption and identifying blind spots of waste generation. The efficiency of blockchain depends on the availability and quality of data (Ma et al., 2024).

Moreover, in last few years, deconstruction emerged as one of the most efficient tools for C&D waste minimisation (Auckland Council, 2019). With deconstruction the Auckland Council-led projects diverted up to 99 % of demolition waste from landfill (Auckland Council, 2018).

C&D waste minimisation is considered an opportunity to achieve Sustainable Construction (SC) and practice a circular economy through circular resources (Purchas & Ainsworth, 2019). The circular economy promotes cradle to cradle thinking, creates job, and save cost and the environment. In addition, it reduces environmental burden and minimises greenhouse gas emissions (Cruz et al., 2019; Nižetić et al., 2019). Moreover, C&D waste minimisation provides effective resource management, client satisfaction, and good community connections (BRANZ, 2014). Therefore, this research is an attempt to identify C&D waste minimisation challenges over the life cycle of project and their remedial measures.

The remainder of this paper is organised as follows: Section 2 discuss methodology; Section 3 shows results; Section 4 gives debate and discussion; Section 5 proposes a waste minimisation framework; and Section 6 concludes this research with future recommendations.

2 Introduction

The data collection was done in two phases: semi-structured interviews and on-site observations. The in-depth semi-structured interviews provide high level and deeper understanding of the subject matter. In the first phase, semi-structured interviews with 37 industry experts were conducted. The participants represented a broad spectrum of CI practitioners:

- Client representatives- Architects, Engineers and Project Managers;
- Contractor- Site Engineers and Construction Managers;
- Policymakers- City Council and MfE employees; and
- Policy influencers- Research organisation's employees, waste collectors and recyclers.

In total, 12 client representatives, 14 contractors, and 11 policymakers and influencers were interviewed to collect the data. The client representatives had the highest average work experience (17 years), followed by policymakers and influencers (12.5 years) and contractors (8.5 years).

The semi-structured interviews identified 25 waste minimisation challenges occurring over the life cycle of a project. The identified challenges were validated for their generalisability through on-site observations. The on-site observations served as a phase two of this research. It gave a realistic view of process and offered a better understanding of how activities are executed in a real-life environment. In addition, observations determined the difference between theoretical underpinnings and practical execution.

In this study, on-site observations of nine residential sites, including three from each; construction, refurbishment and demolition was conducted. The sites were chosen by considering; location of the site; nature of work; and the willingness of organisations to understand and practice waste minimisation.

The on-site observations included the process and participant observation. The researcher observed the daily on-site activities for 30-60 minutes after getting consent from participants. The Participant-as-observer technique was adopted. The data collected through observations was quantitative because only the waste minimisation challenges and their frequency of occurrence were observed without interacting with participants. However, informal discussions with site managers were done on nine sites which added value to the findings. These findings provided external validity to the waste minimisation framework.

3 Results

The semi-structured interviews and on-site observations noted 25 waste minimisation challenges. Table 1 illustrates the challenges and divide them into different project stages. It also shows the interview responses of client representatives (A), contractors (B), and policymakers and influencers (C).

Table 1: Challenges and opportunities in C&D waste minimisation in Auckland

Stage	Challenges	Number of responses by each category			Total re-sponses
		A	B	C	
Number of participants in each category		**12**	**14**	**11**	
Pre-design	Poor contractual require-ments	10	14	11	35
	Greenwashing and green claiming	10	12	11	33
	Lack of early involvement of stakeholders	9	11	10	30
	Lack of education and inno-vation	10	12	8	30
Design	Lack of life cycle thinking	12	14	11	37
	Poor Waste minimisation goals	12	12	11	35
	Material selection and over-ordering	10	14	11	35
	Design out waste	11	12	10	33
	Use of Waste Management Act 2008	12	9	11	32
	Use of pre-fabrication and standardisation	8	10	10	28
Construc-tion	On-site sorting of waste and contamination	12	12	11	35
	Waste reporting and sense of responsibility	12	10	11	33
	Identification and quantifica-tion of waste	10	9	11	30
	Social values of waste	10	8	10	28
Refurbish-	Environmental impact	10	9	11	30

ment	Availability of resources	9	10	9	28
Demolition	10R	12	14	11	37
	Waste levy	12	14	11	37
	Secondary market	11	14	11	36
	Recycling infrastructure	12	10	10	32
	Cost of waste	10	10	10	30
	Role of public and private institutes	10	12	8	30
	Resource recovery and margins on second life products	8	12	10	30
	Application of deconstruction	8	10	10	28
	Waste Management and Resource Recovery Plan	8	8	9	25

Some challenges, such as the implementation of the Waste Management Act (WMA) and 10R, are applicable to all project stages. However, they are classified based on the interview responses and on-site observation. The next subsection discusses each waste minimisation challenge in detail.

4 Discussion

The research findings showed that Auckland CI has an appetite for change. In addition, political and social interest in C&D waste minimisation has increased in Auckland CI. The semi-structured interviews and on-site observation found remedial measures for the waste minimisation challenges. The best possible waste minimisation approaches in Auckland CI are identified as the remedial measures.

In the pre-design phase, all interview participants affirmed the need for a waste minimisation clause in the contractual document. One policymaker mentioned that CI needs to use different instruments to promote waste minimisation through a contract. In total, 25 out of 37 interview participants expressed that waste tracking and monitoring should be a requirement in a contract.

In total, 35 out of 37 interview participants mentioned that a project specific procurement framework helps contractors to differentiate between sustainable and non-sustainable materials. Almost all contractors (13 out of 14) expressed that community workshops and conferences can create awareness about sustainable materials. All contractors stated the need for awareness about eco-labelled materials for contractors and clients. Further, successful implementation of voluntary programmes subsequently contributes to future regulations, if required (A-03).

The early involvement of stakeholders results in efficient decision making to minimise waste (Ajayi & Oyedele, 2018). In total, 32 out of 37 interview participants confirmed that the early involvement of site engineers, architects, and waste handling services during the pre-design stage significantly contributes to waste minimisation. Further, 30 out of 37 respondents expressed the need of Project control Group (PCG)

to bring all project people on one platform to discuss potential remedial measures (B-13). On all construction sites, the contractors created PCG to increase the participation of contractors, clients, sub-contractors, waste collectors and recyclers.

In total, 30 out of 37 interview respondents suggested that cross-functional SC groups should be created to educate clients and contractors. The SC groups encourage innovation by scrutinising existing waste minimisation approaches and examining the feasibility of prospective waste minimisation approaches (B-02).

In the context of design phase, the Auckland CI needs a gentle push towards life cycle thinking to deliver better results and advocate SC (B-03). Most contractors (12 out of 14) believed that life cycle thinking is a client-driven action that needs more attention from clients. In contrast, 10 out of 12 client representatives mentioned that contractors need to educate their staff to induce life cycle thinking from material selection to on-site reuse. One policymaker mentioned that life cycle thinking could be promoted if clients and contractors focus on the environmental and social aspects of waste rather than the economic aspect (C-05).

Almost all interview participants (35 out of 37) confirmed that NZGBC waste minimisation goals are considered widely; however, they are not followed by all industry practitioners. Most client representatives (9 out of 12) mentioned that a regulation should be enforced to achieve the NZGBC waste minimisation goals. In contrast, 10 out of 11 policymakers and influencers argued that a voluntary approach is required to promote waste minimisation goals.

Further, the interview responses (32 out of 37) and on-site observation (6 out of 9 sites) showed that the contractors need a project-specific inventory management plan to select sustainable materials and order them in required quantities. One contractor mentioned that the material selection process should be improved by adopting a holistic approach to studying materials' life cycle (B-12). Another contractor added that building materials' Environmental Product Declaration (EPD) should be considered during the material selection process (B-03). Moreover, a policymaker stated that EPD shows building materials' characteristics that a contractor should observe before buying the material (C-04). On 3 out of 9 construction sites, the site engineer procured EPD building materials, including plasterboard, paints and recycled plastic.

The interview responses showed that all policymakers and influencers encourage contractors to design out waste through the establishment of a design and compliance team. One policy influencer mentioned that the teams' objective should be to eliminate waste in design before it becomes physical waste (C-04). Further, a client representative added that the design and compliance team should manage multiple tasks such as engaging with consultants to improve design efficiency, learning advanced software such as BIM and coordinating with suppliers and manufacturers to use prefabricated building materials (A-07).

The Auckland CI needs to improve the current status of the waste management hierarchy, product stewardship and waste levy through a wide-ranging industry-council partnership (C-02). In total, 30 out of 37 interview participants believed that education on WMA could develop a long term partnership between Auckland Council and the private sector.

In total, 28 out of 37 interview respondents suggested that the Auckland CI should focus on standardised and prefabricated building components use to minimise waste. One contractor mentioned that prefabricated materials such as roof trusses, bathroom ware, modular kitchen and door and wall panels are used by Auckland contractors to practice waste minimisation (B-13).

The on-site observation showed that no sites used BIM; however, site engineers from all construction sites showed interest to use BIM for future projects. In total, 20 out of 37 interview respondents mentioned that Auckland Council and MfE should provide technical and financial support for businesses willing to build new off-site manufacturing plants. Standardisation and prefabrication cannot be a commonplace practice in the Auckland CI without councils' support and industries' acceptance (C-09).

In the context of construction and refurbishment phases, the NZGBC mandate three separate bins for on-site sorting of waste. However, contractors (12 out of 14) argued that due to lack of space, the goal of on-site sorting is often not accomplished. In total, 13 out of 14 contractors suggested that the site engineer need to redraw the material management plan to create on-site space for multiple bins. One contractor mentioned that the material storage layout must be updated after completing each activity (e.g. wall framing, internal wall lining) to use maximum space on-site (B-13). Further, the contractors should be aware of how much waste they are generating from a single house, perhaps from each stage of the house (A-07). All policymakers and influencers supported the act of daily recording of waste streams through photographic evidence. The on-site observation showed that only 3 out of 9 sites tracked the waste. In particular, 2 out of 3 construction sites and 1 out of 3 refurbishment sites tracked the waste and implemented waste minimisation approaches. For example, the plastic and cardboard packing from construction sites were quantified and recycled to minimise waste.

The contractors often do a quick throw of waste and damage the environment without realising the social benefits that could be achieved from waste diversion (NZGBC, 2015). In total, 30 out of 37 interview participants mentioned that the social benefits of diverting waste, such as employment and positive environmental impact, needs to be advertised through workshops and conferences. Further, almost all policymakers and influencers (10 out of 11) preferred community engagement programmes to educate CI practitioners on the social values of waste. In addition, 10 out of 12 client representatives mentioned that contractors should arrange on-site training sessions for site labours to promote social values of waste.

The environmental impact of refurbished materials is often neglected due to a lack of awareness of their reuse or recycling (A-02). All policymakers and influencers suggested that the Auckland CI should have compliance on reusing and recycling the refurbishment waste. One policymaker mentioned that refurbished waste could be minimised by setting quality standards for refurbished materials (C-02). Further, 12 out of 14 contractors proposed to include reuse of refurbishment materials criteria in contractual documents. In total, 25 out of 37 interview respondents advocated that Auckland CI, especially Auckland Council, should support businesses that promote reuse and perform recycling of refurbishment waste.

A client representative mentioned that time and cost required to obtain reusable materials from refurbishment waste should be shared among clients and contractors (A-01). As a result, the burden and responsibilities of minimising refurbishment waste will be shared. In total, 32 out of 37 interview participants agreed to share the collection and processing cost of refurbishment waste. Further, 10 out of 12 client representatives suggested creating a network of contractors, recyclers and clients to increase the promotion of recycled materials obtained through refurbishment waste. In addition, 11 out of 14 contractors advocated that the territorial authorities should incentivise the recycling facilities that process refurbishment waste.

In the demolition phase, in total, 8 out of 12 client representatives advised contractors to focus on the refuse and rethink the approach. One client representative suggested that the contractors should select carpets made from recyclable fibres such as Aquafill (A-10). A policy influencer from Callaghan Innovation mentioned that their organisation provides technical and financial support to a business that makes insulation products from hemp, a bio-based sustainable material.

All interview participants from the contractors' category recommended online applications such as Civil Share and Trademe for resource sharing. Further, a demolition contractor mentioned that contractors such as 'TROW' sends the reusable material to pacific islands and donate it to communities and churches (B-12). On all demolition sites, waste such as timber was reused. Further, on all construction sites, timber off-cuts and scaffolding were reused.

In total, 35 out of 37 interview respondents claimed stated that the Auckland CI needs to invest in infrastructure for remanufacturing building materials (C-11). Further, one contractor expressed the need to set engineering standards for low-value products made from timber, concrete, glass, plastic and plasterboard waste (B-11). All interview participants expressed that Auckland CI practitioners should aim to give second and third life to waste materials by using 10R. Some of the current practices of 10R are (A7; C2; C9):

- Reuse of concrete, timber, plastic, polystyrene, ceiling tiles;
- Extraction of lime from gypsum board to use as a fertiliser for agriculture industry;
- Crushed concrete to fill base for the road;
- Use of plastic bottle waste to make road;
- Plastic waste to replace (at some extent) sand and concrete and;
- Manufacturing of bio-based plastic façade

The NZ government is increasing the waste levy, which is expected to be a positive step towards waste minimisation (A-03). One contractor mentioned that the increase in levy would bring behavioural changes among contractors to divert more waste from landfill (B-08). With the increased levy, all interview participants expressed the need for compliance and monitoring to avoid the illegal dumping of C&D waste.

Further, in total, 35 out of 37 participants mentioned that it is possible to expand Auckland's' secondary market if recycled building materials qualify industry requirements and generate profit for the recycler. A recycling facility manager argued that the secondary market depends on recycling, and the recycling depends on demand from the clients (C-11). On all construction sites, the contractors used recycled

cardboard and plastic for material packaging. The majority of client representatives (9 out of 12) suggested that the CI practitioners need to focus on the design life of materials.

The success of different waste minimisation regulations, laws and acts depends on the availability of the recycling infrastructure (UNEP, 2015). In total, 8 out of 11 policymakers and influencers suggested that the performance of existing recycling infrastructure should be assessed to understand the demand for new infrastructure. Further, the public-private partnership should encourage general (organic) waste recyclers to start recycling C&D waste (B-06). Most contractors (10 out of 14) suggested that MfE and Auckland Council should use waste levy from landfill to incentivise existing recycling facilities. Further, 28 out of 37 participants mentioned that Auckland Council should provide technical support to new businesses to build new recycling infrastructure (B-06).

The Auckland CI needs a viable business model to create a balance between affordability and sustainability. One contractor mentioned that a recycling business survives if it produces sustainable building materials at reasonable prices (B-11). In total, 10 out of 11 policymakers and influencers recommended the Product Stewardship Scheme to share waste minimisation responsibilities and make low-cost sustainable materials. The on-site observation showed that the Product Stewardship Scheme was used for polystyrene waste on all construction sites. Almost all interview participants (35 out of 37) showed positive intent to include other building materials under the scheme.

The interview responses from all participants provided three key themes that required public and private institutes' attention. The themes were: extended producers' responsibilities; Community recycling centres; and Building certification standards. In total, 35 out of 37 interview participants encourage CI practitioners to implement a take-back policy. Companies such as EXPOL had collection bins across Auckland to collect Polystyrene waste. Similar initiatives are required for other waste streams, including but not limited to old carpets, plasterboard, bathroom ware and timber (B-14).

The Auckland region has five community recycling centres and requires more to process different waste streams (A-04). In total, 30 out of 37 interview participants recommended an incentive policy to build new community recycling centres.

All client representatives expressed the need for building certification standards to promote waste minimisation. In total, 31 out of 37 interview participants recommended that the public and private institutes should conduct surveys to ask participants (contractors) about their experience with building certification standards and publish the findings to encourage other contractors (C-06). The on-site observation showed that the contractors received the 6 Homestar certificate for all construction sites.

The Auckland CI needs to create a resource recovery hub with a variety of facilities for commercial business (A-10). The interview respondents (32 out of 37) recommended industry and council partnership promotional events to create a recovery hub. One contractor mentioned that the promotional events could help advocate material recovery, promote recoverable materials and increase consumer awareness about

second life products (B-11). Timber and plasterboard off-cuts were recovered to minimise waste on all construction sites.

In total, 30 out of 37 interview participants were in favour of specifications or certification for recovered products. One client representative mentioned that the public and private sectors could create material recovery guidelines to increase the profit margin for recovering facilities (A-03). For instance, the native timber has high recovery value, but it gives low profit if used as a bio-fuel instead of repurposing (A-01). The guidelines will help recovery facilities to choose the correct recovery method and earn profits through industry demand.

The Auckland CI practitioners reuse, recycle and repurpose the materials obtained through deconstruction (BRANZ, n.d.). In total, 35 out of 37 participants expressed the need for deconstruction promotion through community engagement events. One contractor mentioned that the Auckland Council should reuse the construction materials on council-led projects to promote deconstruction (B-04). Further, 30 out of 37 respondents suggested that training courses for contractors should be conducted to develop their skillset. One contractor mentioned that the training courses should also advise contractors on resource planning to improve waste recovery (B-09). The on-site observations showed that from 2 out of 3 demolition sites, the contractors recovered roof tiles, old timber and steel through deconstruction.

Further, Waste Management and Resource Recovery plan should be implemented for waste minimisation (BRANZ, n.d.). In total, 35 out of 37 interview participants suggested that the REBRI templates need to be included in contracts. One contractor mentioned that a mandatory Waste Management and Resource Recovery plan clause should be added to the contractual document (B-03). Further, 29 out of 37 interview participants recommended that the resource consent process should include Waste Management and Resource Recovery plan. The on-site observation showed that all construction sites and 2 out of 3 demolition sites had Waste Management and Resource Recovery plan. Further, none of the refurbishment sites had Waste Management and Resource Recovery plan.

In total, 9 out of 14 contractors and 8 out of 12 client representatives suggested seeking international practices such as Site Waste Management Plan Regulations(UK government). The majority of participants (32 out of 37) argued that the Auckland Council needs to conduct a feasibility study on the application of such regulation in Auckland and subsequently introduce its local version for the Auckland CI practitioners.

5 Waste Minimisation Framework

The waste minimisation challenges and their remedial measures are combined to develop a waste minimisation framework. The interview responses and on-site observation identified the state-of-the-art of waste minimisation challenges. Subsequently, the challenges were divided into five stages (pre-design, design, construction, refurbishment and demolition). Remedial measure(s) for each challenge were discussed during semi-structured interviews and observed during site visits. Figure 1 (a and b) shows

the connection of each challenge to their remedial measures and proposed a waste minimisation framework for Auckland CI. The maximum number of responses makes a factor most influential in that stage; however, none of the group (client, contractor, policymaker) can be considered most influential for a specific factor based on the current dataset (interviews and observations). The relationship between participants remains dynamic for each factor at each stage.

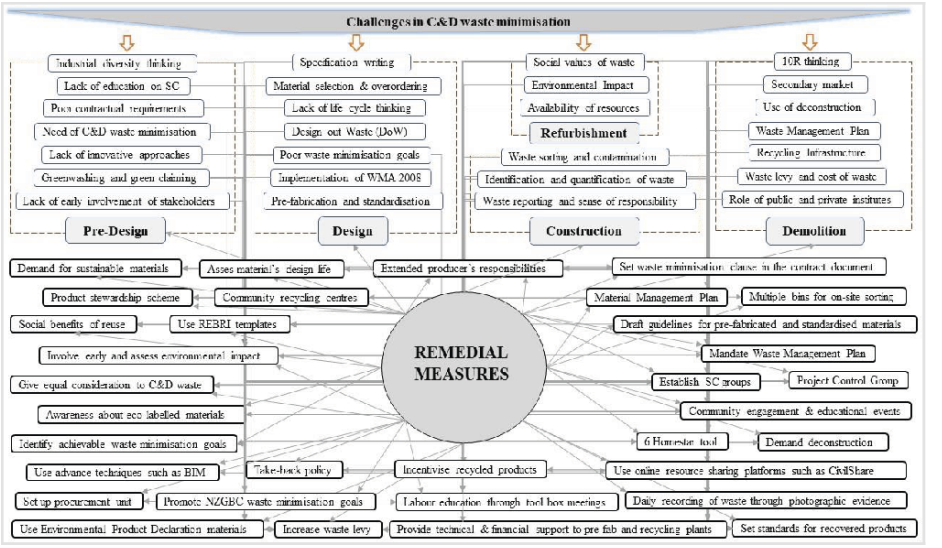

Fig.1 (a). Waste Minimisation Framework

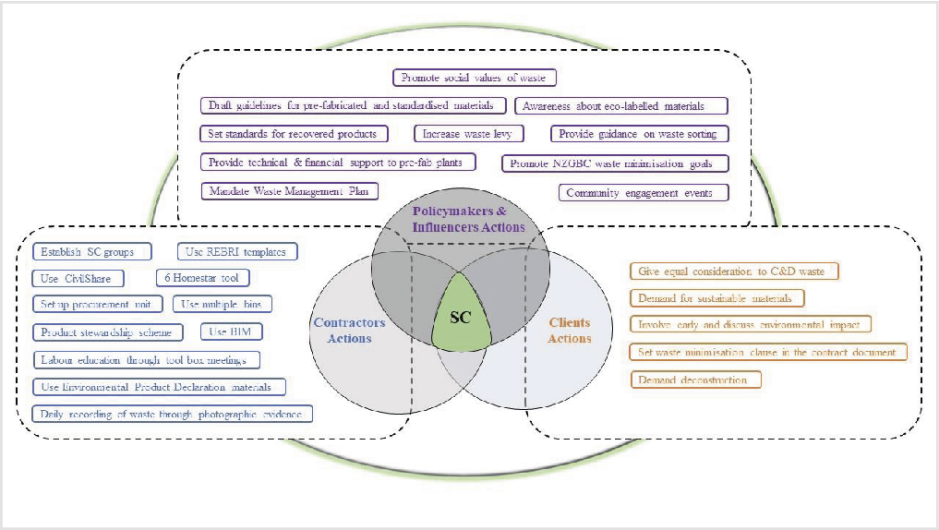

Fig.1 (b). Waste Minimisation Framework

It can be seen from Figure 1(a) that each challenge has one or more than one remedy. For instance, the lack of industrial diversity thinking should be addressed through the demand for sustainable materials, the establishment of SC groups and community engagement workshops. Further, poor material selection and overordering challenges need to be eliminated by setting up a procurement unit, selecting eco-labelled materials, using BIM, and assessing materials' design life. Similarly, some remedies were used to address multiple challenges. For example, product stewardship schemes stimulate 10R thinking, reduce waste costs, and expand the secondary market. In addition, REBRI templates help contractors to develop waste management plan, resource management, waste audits and resource recovery plan.

Figure 1(b) shows actions required from clients representatives, contractors and policymakers and influencers. One group's actions should be acknowledged by the other two groups for their successful implementation. For instance, if policymakers decided to fund community recycling centres and recovery facilities, the client representatives need to demand sustainable materials, and contractors need to perform on-site sorting. Further, if contractors sort waste on-site, policymakers need to set technical standards for reuse and recycle products. Clients' representatives should allow the use of recycled products on their property. In other words, action from one party should be supported by the other two parties to achieve SC through waste minimisation.

6 Conclusion

This study proposed a waste minimisation framework to advocate SC in NZ. The literature findings established a dire need for C&D waste minimisation. Subsequently, 37 semi-structured interviews were conducted with client representatives, contractors, policymakers and influencers to identify the waste minimisation challenges and their remedies. In addition, on-site observations were performed on nine sites: construction (3); refurbishment (3); and demolition (3). In total, 25 C&D waste minimisation challenges were identified over the life cycle of project. In the pre-design stage challenges such as poor contractual requirements and unequal consideration to C&D waste increase waste generation. Further, some of the design stage challenges are: lack of life cycle thinking and waste poor waste minimisation goals. In the construction and refurbishment stage poor waste sorting and reporting, lack of consideration to social values of waste and environmental impact of refurbished waste generates high quantities of waste. In the demolition stage, challenges such as 10R thinking, waste levy, recycling facilities and secondary market contributes to high waste disposal.

The remedial measures for each challenges were found through interviews and on-site observations. In the pre-design stage, clients need to demand sustainable materials. In addition, clients and contractors requires to set a waste minimisation clause in the contract document to promote waste minimisation. In the design stage, contractors should set SC groups and use advance techniques such as BIM to DoW. Further, policymakers needs to provide guidelines for pre-fab building materials. In the construction stage, contractors needs to use multiple bins on site and clients need to demand for waste assessment reports. The policymakers should introduce a compliance on reusing refurbished waste. In the demolition stage, contractors should conduct waste audits at regular interval and prepare a waste management and resource recovery plan. In addition, clients needs to demand for deconstruction rather than demolition. The policymakers and influencers needs to conduct community engagement events to expand the secondary market. In addition, policymakers needs to incentives recycling facilities to encourage recyclers.

The proposed waste minimisation framework is an attempt to attract industry practitioners to promote C&D waste minimisation. The waste minimisation framework serves as a guideline for practitioners to achieve SC. Further, the implementation of framework could open new research avenues for future researchers. This research is an attempt to contribute to United Nations's Sustainable Development Goal 12 that ensures sustainable consumption of resources by achieving the Target 12.5 (substantially reduce waste generation through prevention, reduction, recycling and reuse).

References

1. Ajayi S.O. & Oyedele L.O. 2018, 'Critical design factors for minimising waste in construction projects: A structural equation modelling approach', Resources, Conservation and Recycling, vol. 137, pp. 302-13.
2. Auckland Council 2018, Auckland Waste Management and Minimisation Plan 2018, Auckland Council, Auckland, pp. 1-118, https://www.aucklandcouncil.govt.nz/plans-projects-policies-reports-bylaws/our-plans-strategies/topic-based-plans-strategies/environmental-plans-strategies/docswastemanagementplan/auckland-waste-management-minimisation-plan.pdf.
3. Auckland Council 2019, Cost Benefit analysis of construction and demolition waste diversion from landfill: A case study based on HLC Ltd development in Auckland, Research and Evaluation Unit, Auckland, https://knowledgeauckland.org.nz/media/1071/tr2019-009-cba-on-waste-diversion-from-landfill-homes-land-community-auckland.pdf.
4. Bang,S. & Andersen, B. 2022, Utilising Artificial Intelligence in Construction Site Waste Reduction, Journal of Engineering, Project, and Production Management, issue 12, vol 3, pp. 239-249.
5. BRANZ 2014, Waste Reduction-Construction, Building Research Organisation of New Zealand, New Zealand, viewed July 31 2019, https://www.branz.co.nz/cms_show_download.php?id=5e8633f5234594b316612f186e49687aff5475dd.
6. BRANZ 2019, Construction and demolition produce large amounts of waste, Building Research Association of New Zealand, Auckland, New Zealand, viewed July 31 2019, http://www.level.org.nz/material-use/minimising-waste/.
7. BRANZ n.d., Research reports, New Zealand, viewed 8 July 2019, https://www.branz.co.nz/cms_display.php?st=1&sn=18&pg=17270.
8. Building Act 1991, Building Act, Parliament of Nw Zealand, New Zealand, pp. 1-116, http://www.nzlii.org/nz/legis/hist_act/ba19911991n150118/.
9. Carpenter A. 2020, Auckland Market Opportunit – Circular economy, repurposing construction and demolition waste, https://www.aucklandnz.com.
10. Cruz C.O., Gaspar P. & de Brito J. 2019, 'On the concept of sustainable sustainability: An application to the Portuguese construction sector', Journal of Building Engineering, vol. 25, p. 100836.
11. Huang B., Wang X., Kua H., Geng Y., Bleischwitz R. & Ren J. 2018, 'Construction and demolition waste management in China through the 3R principle', Resources, Conservation and Recycling, vol. 129, pp. 36-44.
12. Ma X., Yuan H. & Du W. 'Blockchain-Enabled Construction and Demolition Waste Management: Advancing Information Management for Enhanced Sustainability and Efficiency', Sustainability, Volume 16, issue 2, pp 721-734.
13. MfE 1997, Waste generation and disposal in New Zealand, Crown Publication, Wellington, New Zealand, viewed July 31 2019, https://www.mfe.govt.nz/publications/environmental-reporting/waste-generation-and-disposal-new-zealand.
14. MfE 2000, Landfill Guidlines, Centre for Advanced Engineering, Christchurch, New Zealand, pp. 1-123, https://www.mfe.govt.nz/sites/default/files/4139_landfill.pdf.
15. MfE 2002, 'A Guide to the Management of Cleanfills ', Ministry for the Environment Wellington,NZ, https://www.mfe.govt.nz/sites/default/files/cleanfills-guide-jan02.pdf.

16. MfE 2009, Environmental Report Card, Ministry for the Environment, NZ, https://www.mfe.govt.nz/sites/default/files/environmental-reporting/waste/waste-composition-2009/waste-composition.pdf.
17. MfE 2015, Construction and demolition wastes Minitry for the Environment, Wellington, New Zealand, viewed August 1 2019, https://www.mfe.govt.nz/waste/waste-list/17-%E2%80%94-construction-and-demolition-wastes-including-excavated-soil-contaminated-sites.
18. MfE 2021, Written evidence to the environment committee briefing on reducing construction and demolition waste going to landfill, NZ Government, Wellington, New Zealand, pp. 1-25, https://www.parliament.nz/resource/en-NZ/53SCEN_EVI_110956_EN7713/aca6c7838a95c02e494c9c1691020a7a6cd5bb2d.
19. Conservation 2007, Te Ara - the Encyclopedia of New Zealand, New Zealand.
20. Nižetić S., Djilali N., Papadopoulos A. & Rodrigues J.J.P.C. 2019, 'Smart technologies for promotion of energy efficiency, utilization of sustainable resources and waste management', Journal of Cleaner Production, vol. 231, pp. 565-91.
21. NZGBC 2014, NZGBC Submission on the Proposed Auckland Unitary Plan (GREEN STAR), NZGBC, New Zealand, https://www.nzgbc.org.nz/Attachment?Action=Download&Attachment_id=356.
22. NZGBC 2015, Strategic Review of the Green Building Market, New Zealand Green Building Council, New Zealand, https://www.nzgbc.org.nz/Attachment?Action=Download&Attachment_id=338.
23. NZTA 2019, Resource Recovery, Government of New Zealand, New Zealand, viewed July 31 2019, https://www.nzta.govt.nz/roads-and-rail/highways-information-portal/technical-disciplines/resource-efficiency/standards-guidelines-and-specifications/resource-recovery/.
24. Purchas C. & Ainsworth A. 2019, 'The C&D waste as a resource: Applying circular economy principles to the construction sector', paper presented to the 31st Annual WasteMINZ Conference, Hamilton, New Zealand, https://www.wasteminz.org.nz/wp-content/uploads/2019/10/WasteMINZ-2019-Construction-and-demolition-waste-used-as-a-resource-applying-circular-economy-principles-to-the-construction-sector.pdf.
25. RMA 1991, Resource Management Act, New Zealand, http://www.legislation.govt.nz/act/public/1991/0069/latest/whole.html#DLM236746.
26. UNEP 2015, Global Waste Management Outlook United Nations, https://www.uncclearn.org/sites/default/files/inventory/unep23092015.pdf.
27. Vilasini N. 2014, 'Generating value in alliance contacts through the lean concepts', Auckland University of Technology, Auckland, https://openrepository.aut.ac.nz/bitstream/handle/10292/7768/ParanaPalliyaGurugeNV.pdf?sequence=3&isAllowed=y.
28. WMA 2008, 'Waste Minimisation Act', in (MfE) M.f.t.E. (ed.)Parliamentry Counsel Office, Wellington, NZ, http://www.legislation.govt.nz/act/public/2008/0089/latest/DLM999802.html.
29. Zaeri F. 2017, 'Exploring the Potential for the Application of Simulation methods in Construction Project Delivery in NZ', Auckland University of Technology, Auckland, NZ, https://openrepository.aut.ac.nz/handle/10292/10616.