The New Zealand Construction Industry and Sustainable Construction through C&D waste minimisation: a review of the life cycle approach

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Abstract: The construction industry is at the core of the global economy and in New Zealand it is the fifth largest industry. One global issue with the construction industry is that it generates a large amount of waste; making it unsustainable. In N.Z., Construction & Demolition (C&D) waste is the most prevalent waste stream and contributes to half of the landfill waste. In recent years, C&D waste has become an alarming issue for the N.Z. construction industry and emphasises the urgent need for waste minimisation. This research study adopts in-depth review of literature. The literature findings on the state-of-the-art of C&D waste minimisation suggested that the current waste minimisation approaches are far from optimum and need integration to increase their practicability. In addition, the review of the literature shows that the N.Z. construction industry needs to adopt life cycle study, i.e. Pre-design, design, construction, refurbishment, and demolition to minimise C&D waste. Further, some of the factors which need special attention are; industrial diversity thinking during pre-design, change in scope while designing, poor resource management during construction, and lack of secondary market. The N.Z. construction industry needs to adopt a circular resource thinking to achieve circular economy; ultimately advocate sustainable construction.

Keywords: Construction industry; sustainable construction; construction & demolition waste; New Zealand

1. Introduction

The word construction has its root from the Latin word "construere" which means putting together (Oxford, 1968). The existence of building construction is parallel to the existence of the human settlement. The modern-day definition of construction includes activities such as build, operate, install, repair, and refurbish (Worksafe NZ, 2017). The construction industry (CI) is an organised performance of such activities by people to create a sustainable built environment (Les, 2006). According to Australian and New Zealand Standard Industrial Classification (ANZSIC), 2006, code E, CI includes the construction of buildings and other structures with their additions, alterations, reconstruction, installation,
maintenance, and repairs, while it excludes manufacturing. The ANZSIC definition was further bifurcated by BRANZ by diving all building structures into three different types; Residential, non-residential and infrastructure (Ministry of Business Innovation and Employment, 2017).

The CI has always been a topic of interest not only for businessmen but also for different institutions and recognised as one of the largest industries in most of the countries due to its competitiveness and profit-driven nature (Timofeeva, 2017). The construction sector is at the core of the global economy. As an industry, construction accounted directly for 6% of global GDP with China as the frontrunner through its 3.1 trillion USD construction market followed by the USA and Japan with 1.2 trillion USD and 470 billion USD respectively (World Economic Forum, 2017). In N.Z., in 2019, the CI worth 39 billion NZD with the largest share of 16 billion NZD from Auckland and predicted to grow until 2023 (MBIE, 2019). However, the growth and contribution brought concerns. The Auckland CI suffered from unsustainability due to its poor resource consumption, high Construction & Demolition (C&D) waste generation, and high energy and water consumption (Purchas and Ainsworth, 2019).

Sustainable Construction (S.C.) has become an urgent need for New Zealand CI due to its rapid growth and increasing concerns. S.C. is a broad topic and includes social, economic, and environmental aspect commonly known as Triple Bottomline Approach (TBL) (Purchas and Ainsworth, 2019). These aspects are interdependent, and enhancing one can result in benefits for the other two. For example, construction projects prove economically viable and provide good social standards of living when the environmental aspect is given proper consideration during the life cycle of the project (Vatalis et al., 2011). From the extraction of natural resources to disposal of C&D waste into landfill CI is encompassed within the environment. Hence, many studies argued that environmental aspect needs special consideration form industry practitioners to advocate S.C. (Akotia, 2014). The environmental aspect is often subject to issues such as air pollution, scarcity of water, poor consumption of natural resources, and high C&D waste generation (United Nations Environment Programme, 2015).

C&D waste is not only a concern of CI in N.Z. but also a global threat to S.C. In N.Z., C&D waste is referred to as "non-household and non-putrescible waste generated from the construction, renovation, repair, and demolition of structures" (Waste Management Institute New Zealand, 2018). Worldwide, every year, a broad group of Municipal Solid Waste (MSW), Commercial & Industrial (C&I) waste, and C&D waste estimated to be 7-10 billion tonnes with China contributing 2 billion tonnes of C&D waste (UNEP, 2015; Wu et al., 2019). In N.Z., 3.5 million tonnes of C&D waste is generated every year, which contributes to half of the landfills nationwide (NZ Transport Agency, 2019). In particular with Auckland, C&D waste is the largest waste stream and some of the factors that influence high C&D waste are; lack of industrial diversity thinking during pre-design; poor selection of green materials while design; inefficient resource handling and management during construction; and lack of secondary market for recycled products after the demolition (Auckland Council, 2019; Purchas and Ainsworth, 2019).

Eliminating waste as per their occurrence over the life cycle of a project, in other words, providing a solution to factors influencing the waste at each stage is referred as waste minimisation (Phillips et al., 1999). The CI adopts different techniques of waste minimisation, but all are classified under two broad categories of; waste minimisation at source and waste minimisation by recycling. The former design out waste, while the latter offers treatment to materials after their useful life (Environmental Protection Department, 2003). Further, CI adopts various waste minimisation approaches such as; waste management hierarchy, guidelines and regulations, and waste minimisation tools. The waste management hierarchy is a structure that represents a step by step procedure to handle the waste (Ministry for the Environment, 1997). The regulations include waste levy and compulsory waste.
management plan and common tools used to minimise C&D waste are; lean construction, supply chain management, and building information modelling (Building Research Association of New Zealand, 2014).

The current situation in N.Z., in particular, Auckland suggest that, C&D waste is a growing concern and an environmental threat. This research adopts a systematic review of literature approach to understand what factors influence high C&D waste generation over the life cycle of a project, the current industry practices of waste minimisation, and opportunities and challenges in waste minimisation. Further, this research offers a standalone viewpoint on factors that needs special consideration from CI to minimise C&D waste effectively.

The remainder of this paper is organised as follows: Section 2 explains historical development, importance and contribution of CI; Section 3 overviews Sustainable Construction and its challenges; section 4 discusses C&D waste and waste minimisation; section 5 reviews various waste minimisation approaches, and section 6 concludes the paper with future recommendations.

2. Construction Industry, historical development, importance and contribution

The word construction has its root from the Latin word "construere "which means putting together (Oxford, 1968). In the context of a building, construction defined as the execution of building works with the management of construction activities (Worksafe NZ, 2017). The construction industry (CI) is an organised performance of construction activities delivered through the consumption of resources (humankind, material, and machinery) (Fernandez-Solis and Arch, 2019). The history of construction and CI have long roots. Agricultural revolution around 12,000 BC years ago triggered early human settlement and humans started to build earth homes instead of hut shelters (Tattersall, 2013). Different parts of the world experience different sites of human settlement in later centuries such as construction site at Catal Huyuk around 7000 BC and Mohanjo Daro around 3250 BC (United Nations Educational Scientific and Cultural Organisation, 2012; Vesilund et al., 2002). Over the years, humans started working as a team and improved their construction skills. The construction of the Great Pyramids of Giza around 2500 BC can be said to be the first notable construction performed by the Construction Industry (Tecle and Mahelet, 2012). The Babylonian king Hammurabi from 18th century B.C. established the first platform of the Construction Industry. He made 282 different edicts which included family laws, administrative laws, and professional contracts. The laws laid the foundation for the establishment of the modern-day CI (Harper, 1904).

N.Z. considered the last landmass in the world to be occupied by humans. The history of first human settlement in New Zealand was still a topic of debate, but most believed that it was dated back around the 13th century (Irwin and Walrond, 2016). The history of first dwelling appeared around the same time, and the early homes in N.Z. were constructed with wooden frames covered in leaves with mats on earth floors (Brown, 2014). The country experienced growth in population around 15th-century when Polynesian people started to settle. As a result, the concept of sleeping houses with several rooms was introduced (Brown, 2014).

Further, pataka (storehouse), and kauta (cooking house) were added to existing houses (Brown, 2014). The European settlers arrived in N.Z. on several occasions between 16th to 18th century, and many of the natives adopted European-styled houses after this period with the introduction of high roofs and glass windows as an addition to timber homes (Watters, 2018). In the late 18th-century building materials such as nails, sawn timber, and metal sheets were first used in N.Z. for construction.
work (Brown, 2014). At the beginning of the 19th century, many construction firms were established, and this laid cornerstone of the N.Z. construction industry. During the mid-19th century, the infrastructure demand had increased demand for factories, schools, hospitals, and offices (Walrond, 2010). In the early and mid-70s, N.Z.’s economy took a downturn, but by late 1980s, it rose with investment from the government and private sector (Stats NZ, 1980). Table 1 shows the economic contribution of the N.Z. construction industry to total GDP and Employment.

Table 1: Contribution of the construction industry to total GDP and Employment of New Zealand

<table>
<thead>
<tr>
<th>Year</th>
<th>Value of Construction Industry (NZD billions)</th>
<th>GDP contribution (%)</th>
<th>Employment Contribution (%)</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>1980</td>
<td>2.6</td>
<td>5.6</td>
<td>7.5</td>
<td>Stats NZ, 1980</td>
</tr>
<tr>
<td>2000</td>
<td>10</td>
<td>3.3</td>
<td>6.2</td>
<td>Stats NZ, 2000</td>
</tr>
<tr>
<td>2005</td>
<td>18.5</td>
<td>4.9</td>
<td>7.7</td>
<td>Stats NZ, 2006</td>
</tr>
<tr>
<td>2010</td>
<td>21.3</td>
<td>4.5</td>
<td>6.2</td>
<td>Stats NZ, 2010</td>
</tr>
<tr>
<td>2015</td>
<td>32</td>
<td>6</td>
<td>9.1</td>
<td>MBIE, 2015</td>
</tr>
<tr>
<td>2018</td>
<td>37</td>
<td>6.1</td>
<td>10</td>
<td>MBIE, 2018</td>
</tr>
</tbody>
</table>

In 2018, for every 10-working people in N.Z., 1 was a construction industry employee with Auckland as the largest shareholder (MBIE, 2018). Residential building activity became the biggest contributor to national construction (MBIE, 2018). In addition to the private sector, the government of N.Z. had also invested in residential construction by introducing "Kiwibuild" programme for 100,000 new homes (MBIE, 2018). The N.Z. construction industry experienced substantial growth in every sector. In the last 40 years, CI witnessed dramatic fluctuations, but it was predicted that until 2023 CI grow gradually (MBIE, 2018). With a total value of 41.4 billion NZD, and Auckland with the highest regional value of 17 billion NZD. The construction Industry in Auckland, and New Zealand, services almost all other industries by creating economic value or by creating infrastructure (MBIE, 2018). Unfortunately, the impact of industry was not solely positive (Auckland Council, 2019). The industry suffered from some serious concerns, including, but not limited to, high material consumption, carbon emissions, high energy consumption, and waste generation (Thomas, 2018; Purchas and Ainsworth, 2019).

3. Sustainable Construction

The word "Sustainable" indicates an ability to perform efficiently for a long time without little or no damage to the environment and the modern-day records suggests that it was first used in 1924 in the context of resource consumption (Cambridge University Press, 2008). In 1973-74, six Middle Eastern countries lowered their import of oil which resulted in higher demand for oil in the international market. The oil crisis introduced uncertainty about future demand and availability of oil; hence many countries choose to optimise their oil consumption to avoid fall of the economy and to maintain the infrastructure growth (Mitchell, 2010). According to Brundtland Commission, "Sustainable Development" can be defined as "Development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (United Nations, 1987).
'Sustainable Construction' often considered as a subset of "Sustainable development" which includes 'cradle to cradle' approach that allows circular resources thinking (NZGBC, n.d.). In the New Zealand CI, SC has often been translated as sustainable building or Green building, and at the beginning of sustainable development in construction the industry used term S.C. for many years until the concept of the green building became famous in N.Z.; all the terms promote balancing of Triple Bottomline Approach (TBL) (Building Act, 2004). The New Zealand Green Building Council defines Green building as 'a building with optimising the consumption of resources throughout the lifecycle of a project (NZGBC, n.d.).

History of S.C. in N.Z. showed that the concept of protecting the environment has always been topic of interest in N.Z. and after the Brundtland Commissions definition of sustainable development, the environmental agenda was reassured again (MfE, 2007). The government of N.Z. took its first initiative towards S.C. by introducing the Resource Management Act (RMA) in 1991. As per Section 5 of the RMA, the use of natural and physical resources has to be optimised and should allow social, economic and environmental well-being for everyone (RMA, 1991). The act provided a sustainable framework towards resource consumption by considering the environment at the centre in the definition of S.C. (RMA, 1991).

Though the act gave equal rights and responsibilities to every user towards protecting the environment, some believed that the act was time-consuming, provides only environmental benefits and hinder overall sustainability (Parliamentary Commissioner for the Environment, 1998). In response to the "only environment focused" argument, the N.Z. government introduced the Building Act in 1992 to address all sustainable aspects under one title (Building Act, 1992). The act established building regulations in 1992 and clause F 5.3.1 from building code promoted the S.C. agenda by covering a range of areas from personal hygiene to energy efficiency. In addition, it also introduced guidelines on how to avoid construction and demolition hazards. Overall, the act established social and economic equality, along with the environmental aspect (Building Act, 1992). In later years, the construction industry and its output grow and to address each environmental issue. The N.Z. government published separate regulations (MfE, 2005). As a part of this, the Energy Efficiency and Conservation Act 2000 was introduced. The purpose of the Act was to promote national energy efficiency and conservation strategy through the introduction of energy efficiency, energy conservation, and the use of renewable sources of energy. (Energy Efficiency and Conservation Act, 2000).

During a similar time, the private sector developed their interest in the sustainable built environment, and BRANZ produced their first report on "Built environment and climate change" (Camilleri, 2000). The research identified different climate-changing factors that can affect the built environment and concluded that the issue of flooding and house overheating needs to address quickly to make CI sustainable. In later years, BRANZ investigated different built environment issues such as leaky buildings, excess building energy consumption, fire-safety, construction waste and provided solutions to such issues (BRANZ, n.d.). To promote S.C. awareness at district levels government introduced the Local Government Act in 2002. The act provided power to the local authority to deal with district-level sustainability issues (Local Government Act, 2002). In the same year, MfE introduced a guide to the management of cleanfills to tackle the waste issue. The guide mentioned that; C&D waste was the primary source of waste sent to landfills (MfE, 2002). The guide provided waste acceptance criteria and the best possible methods to manage cleanfills (MfE, 2002). Further, the N.Z. government introduced the Building Act 2004 in N.Z. (Building Act, 2004).

The Act introduced guidelines for construction, alteration, demolition and maintenance. The Building Code under the Act described how a building must perform in its intended use rather than describing
how it should be design and constructed (Building Act, 2004). The Act introduced several amendments in
the next few years by considering political drivers, social expectations, and adaptation of new construction
technologies. The reformation strengthens overall sustainability framework (Buckett, 2014). However,
researchers believed that the Act can be still improved. Section 18 of the Act mentioned that building
work is not required to achieve performance criteria additional to the Building Code. It allowed
contractors to set a baseline for minimum expectation. Instead, the section can be redrafted as "Any
building work complies to sustainable building guidelines will have priority for resource consent, also, on
validation of the building as a green building the contractor may demand incentives from a client
(Kirpensteijn, 2017). Both public and private sector made their contribution towards S.C. awareness and
implementation. The public sector added an initiative through the introduction of the Green Building
Council (GBC). The New Zealand CI formed their own GBC (NZGBC) in 2005 and collaborated with
WorldGBC a year after (NZGBC, n.d.). It started a new era for S.C. with a synonym of green building. The
WorldGBC defined "green building" as a building that creates positive impacts on the environment
through design, construction, and operation of construction activities; to enhance the quality of life. The
term "green building" evolved constantly, and different countries have different definitions, depending
upon their climate, culture, traditions, socio-economic benefits, and environmental impact (WorldGBC,
n.d.). In other words, challenges faced by CI are listed down under the title of green building, to convert
them into opportunities (WorldGBC, n.d.). In 2008, the N.Z. government introduced the Waste
Minimisation Act (WMA) to tackle the waste issue and promote sustainability (WMA, 2008). Although the
acts published over the years advocate S.C., their implementation was loosely conducted by CI. As a result,
CI suffer from many challenges and Table 2 overviews some key challenges.

Table 2: S.C. challenges in N.Z. construction Industry

<table>
<thead>
<tr>
<th>Challenges</th>
<th>Pre-Design</th>
<th>Design</th>
<th>Construction</th>
<th>Demolition</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Social</td>
<td>Physical and mental health Understanding of CI culture</td>
<td>Political influence</td>
<td>People &quot;At the centre&quot; approach Cultural values of CI people</td>
<td>Less demand for reuse Illegal dumping of waste</td>
<td>Warnock, 2005; Thomas, 2018</td>
</tr>
<tr>
<td>Economic</td>
<td>Feasibility study of resource Precise cost analysis</td>
<td>Quality of life against the cost Rising costs of construction</td>
<td>Labour &amp; capital shortages Adaptation of expensive technologies</td>
<td>Cost of waste collection Low profit on recycled material</td>
<td>NZGBC, 2015; Beacon Pathway, 2006</td>
</tr>
<tr>
<td>Environmental</td>
<td>Balancing ecosystem Education and training</td>
<td>Effect of materials on environment</td>
<td>Atmospheric emission Use of local materials</td>
<td>Skill &amp; expertise to demolish buildings</td>
<td>Byrd and Leardini, 2011;</td>
</tr>
</tbody>
</table>

It can be seen from Table 2 that, some of the important S.C. challenges are poor understanding of S.C.,
cost of construction, resource consumption, energy efficiency, skill shortage, indoor quality, water use
and recycling and C&D waste (Beacon Pathway, 2006; Byrd and Leardini, 2011; Thomas, 2018). The
next section overviews C&D waste and its minimisation.
4. C&D waste

The word "waste" means empty or desolate and received its modern-day meaning in 15th century (Petrák, 2016). According to U.N. Statistical Division "waste can be considered as materials that are not prime products with no further use for their purpose of production, transformation or consumption, and which need to discard, or intend or is required to discard" (UN Statistics Division, 2011). In the context of OECD countries, waste referred to any "unavoidable materials for which there is currently or no near-future economic demand and for which treatment and/or disposal may be required" (OECD, 1997). In the context of building construction, any substance or object generated during C&D process, which the holder discards or intends or is required to discard is known as C&D waste (European Council, 1991). In N.Z., C&D waste referred to waste generated during the construction, repair, maintenance, refurbishment, and demolition, including contaminated soil (Auckland Council, 2019). Figure 1 shows the C&D waste generated in 2018 in different regions of the world.

![Figure 1: C&D waste generation in different regions of the world (UNEP, 2015; World Bank Group, 2018)](image)

In N.Z., the 1990s construction boom put C&D issue upfront, and in 1995 C&D waste became third-largest waste stream after organic and paper and ever since it is increasing (MfE, 1997). By early 2010, C&D waste represented a quarter of total landfill waste, and by 2016, half of the landfill (Auckland Council, 2017). In 2018, C&D waste became one of the largest waste streams in N.Z., with 20 % of all waste going to landfill and 80 % to Cleanfill (NZ Transport Agency, 2019). In particular, with Auckland, C&D waste was the largest waste stream and contributed to half of the landfill waste (Auckland Council, 2018). Various factors influence high C&D waste, and Figure 2 shows some of the key factors considering the life cycle of a project.

![Figure 2: Factors influencing C&D waste generation (Ali et al., 2018; Islam et al., 2019)](image)
4.1. Waste minimisation

C&D waste minimisation often guided by the need for a sustainable built environment and considered as a subset of waste management (BRANZ, 2014). There are different perspectives to define C&D waste minimisation, and all are considered under two broad categories; i) at source, and ii) by recycling (BRANZ, 2014). Waste minimisation 'at source' referred to the minimum consumption of resource at the beginning of the project, while 'at recycling' referred to the usage of recycled materials that have reached the end of their useful life (BRANZ, 2014). In addition, by source waste minimisation design out waste before it becomes physical waste, while waste minimisation by recycling deals with physical waste and minimises waste through reuse and/or recycle and/or recover (EPD, 2003). The CI has adopted various waste minimisation approach, as explained in the next section.

5. C&D waste minimisation approaches

5.1. Waste Management Hierarchy

The waste management hierarchy was introduced in N.Z. in the early 90s. In 1990 the N.Z. government introduced National Waste Management Policy to minimise solid waste through the application of reduction techniques (MfE, 1997). The policy promoted recycling at the local level, and in 1992 it was revised to add a waste management hierarchy for achieving the best possible waste minimisation results (MfE, 1997)). The N.Z. version of the waste hierarchy includes six different steps; Reduction, reuse, recycle, recover, treat, dispose or residual dispose. The first step of the guide (reduction) was most preferred to increase sustainable standards while the last step (dispose) was least preferred to avoid degradation of such standards (MfE, 2009). The current practices in N.Z. lack in implementing the waste management hierarchy effectively, and as a result, C&D waste is becoming a national concern (Purchas and Ainsworth, 2019).

5.2. Guidelines and Regulations

The conservation of the environment through guidelines and regulations has been the interest of the N.Z. government for decades (Nathan, 2007). Some of the earliest examples of such interest are Nelson Water Works Act (Nelson Waterworks Act, 1863) for the wastewater issue and Dunedin city Fish-markets and Empowering Act (Dunedin City Fish-Markets And Empowering Act, 1918) for addressing the issue of waste product from fish. During the early 90s, the government increased its concerns over resource efficiency and published RMA (RMA, 1991), building regulations (Building Act, 1992), and N.Z. waste strategy (MfE, 1997). Further, between 2000–2008, different waste management regulations were published to achieve S.C. For example, landfill guidelines in 2000 (MfE, 2002a), zero waste strategy in 2002 (MfE, 2002b), cleanfill guidelines in 2002 (MfE, 2002a) and the Waste Minimisation Act in 2008 (WMA, 2008). The highlights of the Act were the introduction of the waste levy, product stewardship, and the role of territorial authorities to promote waste minimisation and management. Clause 43 of the Act required territorial authorities to have a Waste Management and Minimisation Plan (WMMP), and clause 51 required waste assessments (WMA, 2008).

5.3. Tools

In addition to the guidelines and regulations enforced by governmental organisations, there are few non-governmental organisations such as BRANZ who has own C&D waste minimisation guidelines.
dedicated to helping industry and community (BRANZ, 2014). The Auckland council and BRANZ collaborated to resolve C&D waste issue and formed the Resource Efficiency in the Building-Related Industries (REBRI) programme in 1995 (BRANZ, n.d.). The REBRI programme grows over the years and published waste minimisation guidelines from project tendering to the deconstruction stage (BRANZ, 2014). The REBRI programme adopted LCA and provided different tools such as resource routing calculator, waste management plan, recycling directory, and waste transfer form (BRANZ, n.d.). The use of Lean Construction and Supply Chain Management for minimising C&D waste was not a common practice in N.Z. However, few validated case studies suggested that the application of lean tools helped to minimise C&D waste through source reduction and on-site sorting (Vilasini, 2014) and practice of SCM for material procurement promotes environmental benefits (Samarasinghe, 2014). The use of Building Information Modelling for C&D waste minimisation had been in practice worldwide since long, and in N.Z., it had been around for a decade (Construction Excellence NZ, 2010). Similarly, simulation in construction had also been avoided. However, it had been argued that simulation is the future of New Zealand CI as it provides better decision-making choices by understanding the real-time process which helps to track the origin of the waste (Zaeri, 2017).

6. Conclusions and future recommendations

The rapid urbanisation and increasing demand for infrastructure in N.Z. are posing a threat to a sustainable built environment. The in-depth review of the literature suggests that advocating S.C. through C&D waste minimisation while considering the life cycle of a project received less interest from both academic scholars and industry practitioners. Although the N.Z. government and private sector have introduced guidelines, regulations and tools for waste minimisation, the construction industry still lacks in providing desired outcomes. Some of the factors which require special attention from the construction industry are; early involvement of stakeholders, eco-labelling of materials, coordination and communication among all stakeholders, specification writing, handling and storing of material, waste sorting and management, and secondary market for recycled products. This study proposes findings based on the literature and recommends further study to be done in practice to integrate the current findings. In addition, the study opens a new pathway to understand C&D waste through a life cycle approach in N.Z. construction industry, and more studies in this area are required to propose a waste minimisation framework.

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